Intellectual Property, Blockchains, and Smart Contracts: A Brief Review of Their Relationships and Interactions

Erik Schüler
PhD, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil.
Professor EBTT, Instituto Federal do Rio Grande do Sul (IFRS), Veranópolis, RS, Brazil.
http://lattes.cnpq.br/1046844040379714
erik.schuler@ifrs.edu.br

Celso Luiz Salgueiro Lage
PhD, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brazil.
Senior Specialist in Industrial Property in Biotechnology, Instituto Nacional da Propriedade Industrial (INPI), Rio de Janeiro, RJ, Brazil.
http://lattes.cnpq.br/0454490389384070
clage@inpi.gov.br

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ABSTRACT

This article presents a literature review of various solutions and analyses concerning the use of blockchains and/or smart contracts to manage aspects of intellectual property assets. These include proper registration to establish prior art, ownership traceability, copy control, payment automation, contract execution, and related functions. The analyses focus on the application of these technologies to copyright, industrial property, sui generis protection, and technology transfer agreements. The methodology comprised a keyword search in scientific databases, followed by a qualitative content analysis to extract the most relevant points from each document. Overall, the findings indicate that most proposed applications address copyright-related issues, followed by patent-related uses. In the majority of proposed solutions, blockchain registration is restricted to information about the asset, without necessarily storing the asset itself on the blockchain.

Keywords: intellectual property; blockchain; smart contract; NFT.

INTRODUCTION

In 2008, following several unsuccessful attempts, a definitive solution was finally proposed for creating a completely virtual currency with transactions that could be fully validated without the need for financial institutions (Nakamoto, 2008). This led to the emergence of Bitcoin and, with it, an even more significant contribution: the blockchain. Entirely based on previously known concepts (Narayanan, 2017), such as hash functions, Merkle trees, Proof of Work, public keys, and peer-to-peer (P2P) communication, the white paper that introduced Bitcoin brought these ideas together to propose a decentralized chain of blocks designed to store financial transactions. These transactions are validated by network participants (nodes), thereby preventing issues like double spending, a key motivation behind Bitcoin's creation, while permanently recording all activity for future verification.

In 2014, also drawing on existing concepts (Szabo, 1997), Buterin V., in the *white paper* that introduced the Ethereum network, proposed the use of blockchain-based smart contracts. These would make it possible not only to execute Bitcoin-like transactions but also to run and validate computer programs in a decentralized manner, without relying on third parties. Moreover, Ethereum was designed to support a Turing-complete programming language, enabling any computer program to be "replicated" in the form of smart contracts (Buterin, 2014, p. 13).

As an obvious next step, blockchain-based networks, with or without smart contract support, began attracting attention for uses beyond their original financial transaction purposes (Joshi, 2018, p. 133). The rise of Non-Fungible Tokens (NFTs) (Wang, 2021; Fairfield, 2021), built on smart contracts and traded on blockchain networks, has so far centered almost exclusively on the sale of "unique" images, sometimes for tens of millions of dollars (Ross, Cretu & Lemieux, 2021, p. 2263), but offers many other possibilities. The tokenization of real-world assets ("transposing" the physical into the virtual) expands NFT applications, making it possible, for example, to trade a commercial building divided into fractional shares, each representing a portion of the property's total value (Allen, 2020).

In line with these developments, this article conducts a systematic literature review that analyzes the use of these technologies – blockchain, smart contracts, NFTs, and tokenization – in relation to various domains of intellectual property. This includes copyright, industrial property, sui generis protections, and the transfer of such assets. Broadly speaking, the text will be structured around an analysis of potential applications of blockchain, smart contracts, and NFTs/tokenization in the protection and/or transfer of technologies, all drawn from the available scholarly literature. As will be shown, most of the proposed solutions to date focus on copyright-related use cases, followed by applications for patent management. In the majority of cases, the proposed use of blockchain involves the registration of data related to the assets, rather than storing the assets themselves on the blockchain, due to certain technical limitations.

This article is structured into sections on methodology and results analysis, including a brief conceptual review and an overview of the search procedures. Based on the review, it aims to provide a comprehensive overview of the various applications of these technologies to different aspects of intellectual property assets, highlighting potential trends toward either the continued development or the decline of such applications.

METHODOLOGY

This article is based on documentary analysis conducted through a brief literature review in the Scopus database, using the terms “blockchain,” “smart contract,” “NFT,” and “intellectual property” individually. To complement this review, additional searches were conducted combining the terms “blockchain,” “smart contract,” and “NFT” with each category of intellectual property protection (copyright, industrial property, and sui generis protections). In general, the search string used for document title–only searches was structured as follows:

search_string = part_A + part_B

The part_A segment remained constant, defined as:

parte_A = (blockchain OR NFT OR “non fungible token*” OR “smart contract*”)*

The part_B segment varied according to the intellectual property category under investigation. **Table 1** summarizes the number of documents found exclusively in Scopus using these search strings.

Table 1 – Summary of literature review results

part_B search string	Number of documents returned
“intellectual property”	36
copyright	79
“industrial design”	00
“software registration”	00
(cultivar OR “plant variet*”)	00*
trademark	01
“integrated circuit topography” OR “integrated circuit layout”	00
“geographical indication”	01
patent	07**
franchis*	00
“know how”	00
“trade secret”	00

Source: prepared by the author, 2022.

* The term “NFT” combined with “cultivar” returned several documents, but all referred to “Nutrient Film Technique.”

** The search yielded 37 documents, but 30 concerned patents related to blockchain technology itself.

In addition to searches in scientific literature databases (Scopus), given the low number of results obtained, freely accessible online sources (especially Google Scholar) proved fruitful for these topics. Maintaining peer review as a minimum criterion, much of this material could serve as a basis for the study.

Accordingly, this research is exploratory in nature, intended to develop familiarity with the relationship between the aforementioned technologies and intellectual property, clarify the issues involved, and enable the formulation of hypotheses. The retrieved documents were analyzed, and a selection is presented in this work to draw conclusions on the potential uses of these technologies in intellectual property management.

ANALYSIS AND DISCUSSION OF RESULTS

The analysis and discussion are divided into two parts. The first offers a brief review of concepts related to blockchain, smart contracts, NFTs, and tokenization. The second addresses possible interactions between these technologies and different intellectual property assets.

Conceptual Review

Before proceeding with the analysis, a brief review is necessary to establish a basic understanding of the technologies involved. This will also create the foundation for questions whose answers will lead directly to some of the potential applications of these technologies within certain branches of intellectual property.

Blockchain

The concept of blockchain, and its frequent association with Bitcoin, sometimes gives rise to misunderstandings. To clarify the distinction between blockchain and Bitcoin—while still acknowledging that Bitcoin is dependent on blockchain—let us consider the following example:

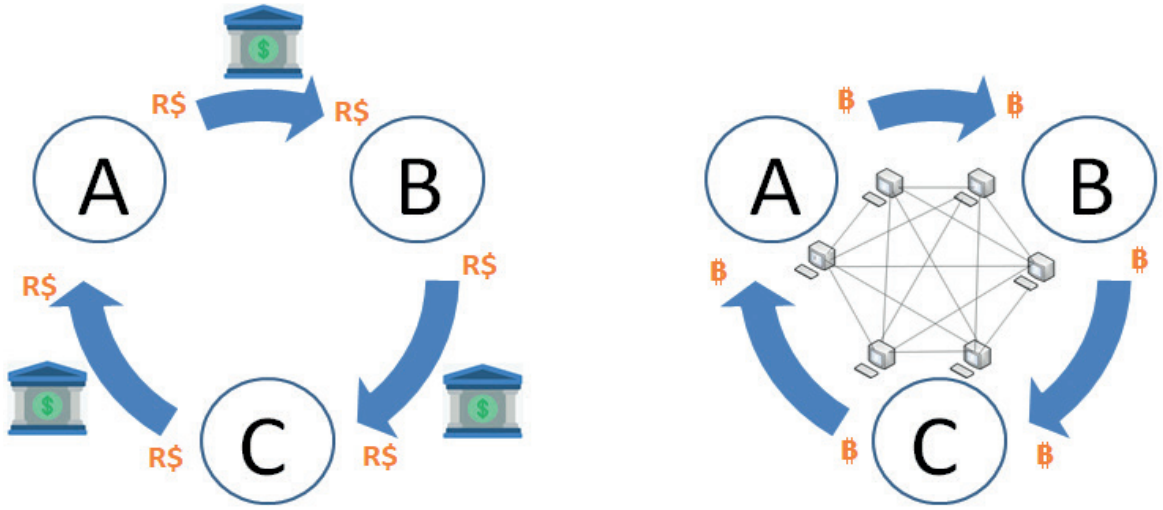
The concept of blockchain—and its frequent association with Bitcoin—often leads to misunderstandings. To clarify the distinction between blockchain and Bitcoin, while recognizing the latter’s dependence on the former, consider the following example: Suppose individual A purchases a product from an online store owned by B. Upon completing the purchase, A’s financial institution records the transfer of a certain amount in Brazilian reais to B’s financial institution (the same reasoning applies if both use the same bank, in which case the transfer is from A’s account to B’s account). Later, at the end of the month, store B pays the salary of its employee C. This payment, made via bank transfer from B’s account to C’s account, is again recorded by B’s bank as the outflow of a given amount in reais to C’s bank. Finally, in the same example, employee C uses part of their salary to buy a product from A’s online store, following the same flow of funds (in reais) already described.

Evidently, in this example, there was never a need for physical cash. The entire cycle of financial transactions can be carried out solely by recording fund transfers from one financial institution to another, which is done by entering numerical values in centralized databases (each bank maintains its own database). In general terms, monetary transactions are essentially database records of value movements, and there is no need for physical cash to change hands except in specific situations.

Now, by replacing the “real (R$)” currency with “bitcoin (B)” in this example, we can understand the basic idea behind virtual currencies. Without making any value judgments about whether or not such currencies are backed or tied to the production of goods and services, we can say that this type of financial resource is essentially a record of transfers between different parties. Furthermore, if we replace the term “financial institution” with “blockchain,” we can clearly see the interdependence between virtual currency and its underlying technology.

A blockchain is nothing more than a decentralized database (unlike the centralized ones maintained by banks) that records financial transactions. Without delving into the technical details of different consensus mechanisms (Proof of Work, Proof of Stake, etc.), the validation of these transactions occurs when a majority of the blockchain network’s participants, known as nodes, agree on the transaction’s authenticity. Once recorded, these transactions become permanent and immutable (Nakamoto, 2008, p. 3). Both scenarios described can be illustrated schematically in **Figure 1**.

Figure 1 – Example of a financial transaction with value records (a) in a centralized database and (b) in a decentralized database

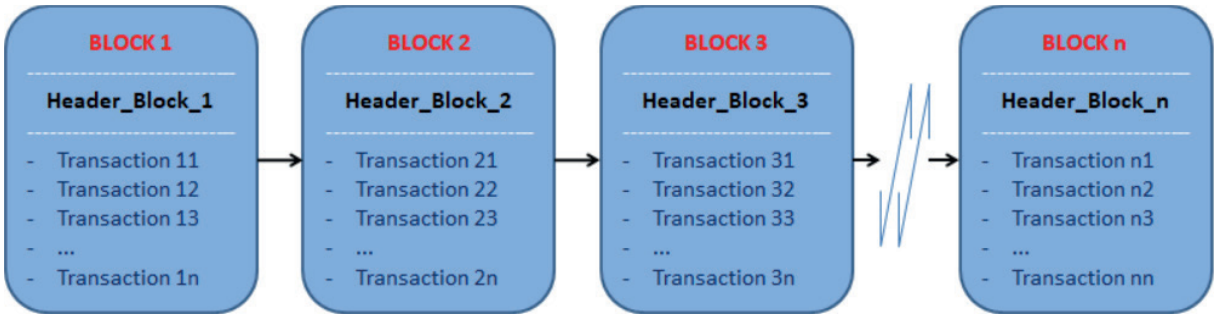


(a) (b)

Source: Prepared by the author, 2022.

The term blockchain derives from the fact that transactions are recorded in blocks which, once filled, are closed and linked to the next block, through the use of hashes, containing new transactions, as illustrated in **Figure 2**.

Figure 2 – Simplified illustration of a blockchain



Source: prepared by the author, 2022.

Considering this graphical representation, an initial question arises that can point to possible applications of this technology in intellectual property asset management: what if, instead of financial transactions, other types of information were recorded in each block? For example, the sale of a specific asset or a record of prior use of a particular technology or distinctive sign?

Smart contracts

Before addressing possible answers to the question above, it's important to clarify the concept of a smart contract. Using a practical example, imagine two users, A and B, exchanging bitcoins. For their transactions to take place, each must be linked to a digital wallet (Buterin, 2014, p. 24).

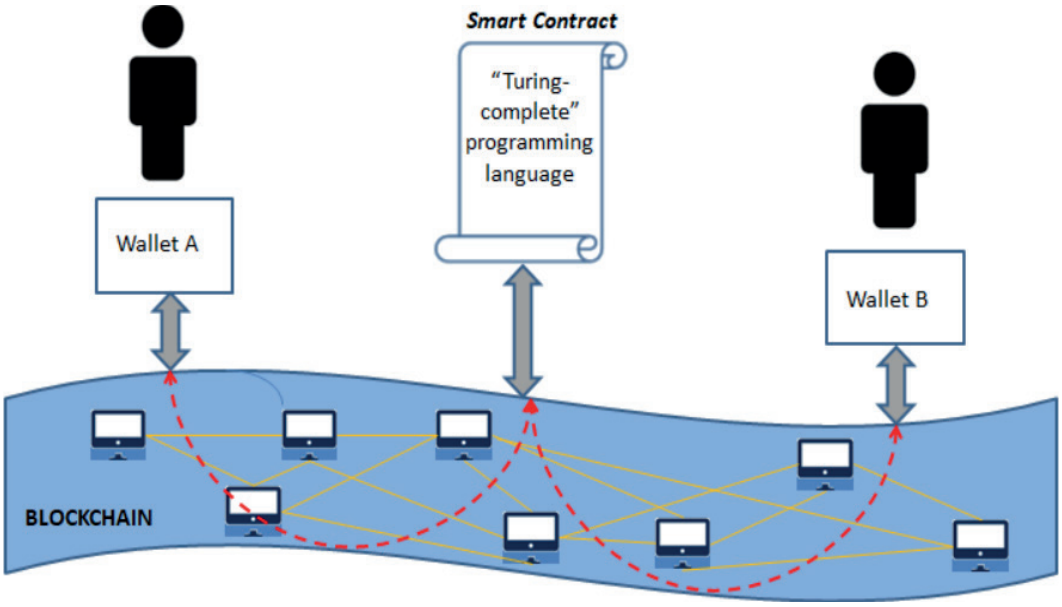
Now, imagine a third digital wallet that isn't associated with any individual but consists of a set of logical instructions that execute once a predetermined condition is met. This third wallet, whose participation rules are determined by its embedded code, represents the concept of a smart contract.

Although blockchain and smart contracts are entirely independent technologies (the concept of smart contracts predates blockchain by many years), the use of smart contracts expanded exponentially with the advent of blockchain. Once the conditions for executing a smart contract are met, the resulting actions are carried out and validated by the blockchain, much like financial transactions. In other words, the execution of a smart contract doesn't require third-party authorization; it only needs the programmed conditions to be fulfilled.

While it's technically possible to implement smart contracts on the Bitcoin blockchain, the emergence of the Ethereum blockchain introduced a crucial feature that significantly contributed to the concept's spread: support for smart contracts written in a Turing-complete

programming language. This makes it possible for any program developed on a computer to be “replicated” in the form of a smart contract and thus validated by the blockchain where it is instantiated (Buterin, 2014, p. 13).

Figure 3 – Simplified illustration of a smart contract instantiated on a blockchain



Source: prepared by the author, 2022.

A second question arises regarding these new technologies and intellectual property: what if the pre-established rules in smart contracts were designed not only to carry out financial transactions (as originally conceived by the creator of the Ethereum network) but also to transfer other types of assets, such as royalties from musical productions or the ownership of a given asset?

NFT – Non-Fungible Tokens and Tokenization

Finally, it is necessary to briefly explain the concepts of tokens, NFTs, and tokenization. The first can be understood as a certificate of ownership for something. Consider, for example, a poker chip: it cannot be used to buy a newspaper, but it represents a certificate of ownership of a certain value that can only be exchanged for money at the establishment where it was issued. In the context of virtual currencies, each blockchain has its own token. The Bitcoin blockchain has a token of the same name, while the Ethereum blockchain has a token called Ether.

The concept of an NFT is also quite straightforward if one understands the idea of fungibility. Two five-real banknotes can be exchanged for a single ten-real banknote because money (like many types of commodities) is fungible, meaning it can be exchanged for something of the same kind without a loss of intrinsic value. In contrast, two rare stamps cannot simply

be swapped for a single stamp (whether more or less rare), as these are non-fungible items. Bringing this concept into the virtual realm of blockchain, one Bitcoin (the token linked to the Bitcoin blockchain) can be exchanged for its equivalent value in Ether (the token linked to the Ethereum blockchain), since both are virtual currencies whose values can be converted into each other. On the other hand, an image of a yellow cat cannot, in principle, be substituted for an image of a red dog.

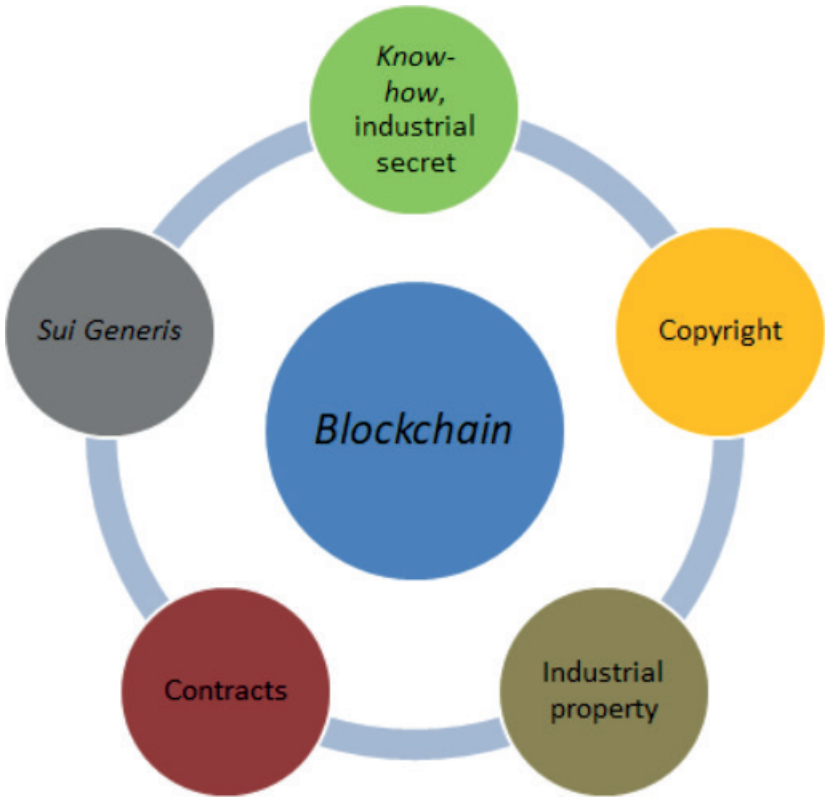
Without making any value judgment regarding the utility of exchanging images such as these, the concept of Non-Fungible Tokens (NFTs) remains valid. In general terms, an NFT is a token, a certificate of ownership, for something that is unique and, therefore, non-fungible. It serves to prove that a given asset (digital or physical) “belongs to” someone, meaning it is linked to their digital wallet. NFTs are closely related to smart contracts, as their ownership management and transfer mechanisms are carried out through smart contracts, following the ERC-721 standard (Fairfield, 2021, p. 22).

Therefore, tokenization can be defined as the process by which a token represents something already created in the digital world (such as the well-known Bored Ape or CryptoKitties) or something existing in the physical world (such as real estate, securities, works of art, or intellectual property assets) and is “brought” into the digital environment, that is, tokenized. Tokenization is thus the transposition of something real (preferably with economic value) into the virtual realm, preserving its original value, whether represented by a single token or divided into multiple tokens.

Possible Uses for Different Intellectual Property Assets

When discussing intellectual property, it is necessary to take into account its various subdivisions and the different assets encompassed within them. For this study, we analyze the different uses of blockchain, smart contracts, and NFTs, considering the aspects of intellectual property presented in **Figure 4**.

FIGURE 4 – Aspects involved in intellectual property



Source: prepared by the author, 2022.

From the outset, it is possible to identify certain limitations to the use of these technologies when linked to specific branches of intellectual property. For example, in the case of a patent—an asset associated with industrial property—it is clear that merely recording a patent application in a blockchain does not guarantee exclusivity. It is the responsibility of the State (in Brazil, the Instituto Nacional da Propriedade Industrial – INPI) to examine and potentially grant the patent. On the other hand, registering an already granted patent in a blockchain could facilitate, for instance, monitoring its history of assignments and/or licensing (Brasil, 2020).

The following subsections will present a brief analysis for each of the topics shown in **FIGURE 4**, outlining possible uses and different perspectives regarding blockchain-related technologies in various aspects of each asset.

Copyright

Author's Rights and Copyright

According to Article 18 of Law No. 9.610 of February 19, 1998, which governs copyright (author's rights and related rights) "A proteção aos direitos de que trata esta Lei independe de registro" (Brasil, 1998a, p. 3)[1]. Thus, it is sufficient for the author to express their creation in any medium or fix it in some tangible form for their rights to take effect.

However, if the author were to record their creation in an immutable and easily verifiable system, such as a blockchain, certain aspects related to registration and the transfer of ownership could be facilitated.

Some solutions, particularly in the context of copyright protection[2] have been discussed in the literature. Among the assets for which such solutions are most common, the music industry stands out as one of the primary beneficiaries. For instance, Gürfidan and Ersoy (2021) propose creating a blockchain-based music wallet. The idea is that by using encrypted audio files stored in a blockchain, only authorized users (those holding the correct key) would be able to access the files. Still within the realm of copyright, Bell (2016) highlights the challenge of whether an author can enjoy copyright protection without necessarily revealing their real identity (by using a pseudonym or remaining anonymous). In short, the author would be unable to register, transfer, or claim their copyright without revealing their identity or relying on a trusted third party to represent them. The proposed solution is to use public keys (a digital identity associated with each blockchain user, which can be linked to pseudonyms rather than a person's real name) to record transactions on a blockchain, thereby preserving anonymity. This way, an author could use a blockchain to assert authorship of works through digital signatures and provide a channel for transactions with parties interested in licensing or purchasing their rights. The text also briefly addresses the issue of proving authorship. Through the use of timestamping[3], an author could link the first access to a given file without necessarily placing the file itself on the blockchain, since, as Bell (2016, p. 465, our translation) states, "[...] o autor de um trabalho é sempre a primeira pessoa a ter acesso a ele" (Bell, 2016, p. 465, our translation)[4].

There are also solutions that combine technologies to achieve various protective effects. Li (2022a), for example, proposes converting songs into NFTs, which would then be recorded on a blockchain. Combined with a recommendation system based on artificial intelligence (AI), this approach aims to increase the efficiency and transparency of protection. Alchaqmaqchee (2021) focuses on digital images, generating a corresponding hash for each

1 Translation: "The protection of the rights provided for in this Law is independent of registration" (Brasil, 1998a, p. 3, editorial translation).

2 While maintaining the distinctions between copyright and direito autoral (author's rights), the solutions proposed for the former can, in principle, be adapted to the latter, provided that the specific rights involved (e.g., reproduction rights, performance rights) are taken into account.

3 A timestamp recorded in each block of transactions added to the blockchain, ensuring that those transactions occurred at that specific moment.

4 Original: "The author of a work is always the first person to have access to it" (Bell, 2016, p. 465).

one. Together with a second hash derived from the image itself and copyright information stored in the InterPlanetary File System (IPFS)[5], these elements are stored on a blockchain. A more comprehensive solution is presented by Lin *et al.* (2020), whose proposal, implemented via the Maker-IP system, involves blockchain registration not only of copyrights but also of patents, trademarks, geographical indications, plant varieties, and other assets. For some of these, the use of Internet of Things (IoT) concepts is suggested – for example, to control products associated with a specific indication of origin.

Some proposals are limited to specific objects, such as the solution presented by Ren *et al*. (2021) for copyright control of geographic maps, or systems designed specifically for managing copyright in the fashion industry (Burstall; Clark, 2017; Sacha, 2019). In other cases, the scale of financial transactions has generated a variety of approaches. Copyright issues involving video files, similar to those in the music industry, fall into this category. The possibility that a video hosted on one platform (e.g., YouTube) may have originated from another (e.g., TikTok) can create financial disputes between platforms if copyright rules are not correctly applied.

A common approach to video monitoring involves embedding watermarks in various frames. However, this method presents challenges, including vulnerability to watermark removal attacks, degradation of the watermark during compression and other forms of manipulation, and potential reductions in the video's quality when the watermark becomes visible due to low invisibility characteristics (Wu *et al*., 2022). Other approaches rely on centralized third-party validation of copyright registration, introducing a potential weakness (Wu *et al*., 2022, p. 2). Still others use key-based file encryption, which raises concerns about key management and related complications (Wu *et al*., 2022, p. 2).

From this perspective, Wu *et al*. (2022) propose avoiding watermarks altogether by extracting features from the video using various algorithms. These features, taken from specific key frames, are stored on a blockchain, enabling rights to be transferred and/or authenticity to be verified (Wu *et al*., 2022, p. 5). Similarly, Yang and Yu (2022) suggest detecting facial expressions in videos through neural networks, with the extracted features stored as log-type files[6] on a blockchain. Each feature set, according to the authors, is unique and corresponds only to the original video. Zheng *et al*. (2021) combine watermarking with blockchain storage: after generating watermarks specific to each video, they create a hash of the watermark which, together with the copyright owner's identification, is stored on the blockchain for later validation.

A second aspect of copyright involves licensing or assignment, generally to facilitate royalty and payment control. Rosenblatt (2019) analyzes copyright and royalty payment issues, noting that each piece of music involves two copyrights: one for the composition/lyrics and

5 A distributed storage system based on peer-to-peer exchanges (https://ipfs.tech/).

6 A term commonly used to designate files generated by programs to record occurrences and events during their execution. Essentially, it is a file containing information about another file or program.

another for the performance. The study examines blockchain's applicability in two contexts: the chain from a song's creation to its delivery to distribution services, and the manner in which these services deliver music to end users.

In the first context, ensuring that performances are properly linked to the compositions they embody could be enhanced through blockchain. Ideally, each time a user downloads or streams a song, the distributor would record—on a blockchain accessible to all interested parties—identifiers for both the composition and the performance. This would enable each rights holder (or other stakeholder) to review the record and initiate a royalty payment executed via smart contract. All recordings and transactions would be available to stakeholders, creating an auditable trail to help resolve disputes. Beyond automating royalty payments, the main advantage of blockchain in this context would be reducing the music industry's reliance on centralized private databases, which are currently the standard.

In the second context, according to Rosenblatt (2019), blockchain would offer limited benefits. Digital music distribution, which has existed for decades, has shifted from downloads to streaming, allowing users to listen to music on demand without owning it (as was the case with vinyl records or CDs). In a blockchain-based model, the artist could release music linked to a token (recorded on a blockchain) containing unique identifiers for each user. If a user wished to transfer their token (by selling, lending, renting, etc.), they could simply add a new record to the blockchain establishing the new owner. It is also possible to associate a hash with each file, allowing the user to recalculate it to verify authenticity, along with other minor variations of this method (Rosenblatt, 2019, p. 18).

A third aspect to consider, though certainly not the last, is the issue of potential controls over territoriality in the transfer of copyright. Bodó, Gervais, and Quintais (2018) raise the following question: although copyright registration benefits from "automatic" coverage in all signatory countries of the Berne Convention, the principle of territoriality must still be upheld. Therefore, local legislation must be respected, whether due to the various forms of license exploitation or the types of rights that may be licensed or assigned (e.g., translation into one or more languages, reproduction, performance, execution). Moreover, since a creator is not obliged to formally register their work in each of the 176 signatory countries of the Convention[7], the question arises of how to control these variables.

The authors argue that two forms of coordination should be considered to address these issues. One is off-chain coordination, matters to be resolved between parties without the use of blockchains, which is suitable for conflict resolution, particularly regarding underlying causes. The other is on-chain coordination, where issues can be resolved automatically through smart contracts instantiated (and therefore validated) on a blockchain. The simplest solution, the authors conclude, would be for authors to retain all rights and then:

7 The article was written in 2019, and the number of signatories is now outdated; it has since increased to 181.

> Cada autor possa permitir algumas utilizações sob licenciamento exclusivo, se e quando apropriado, e utilizar a tecnologia *blockchain* para licença em massa, de maneira não exclusiva (Bodó; Gervais; Quintais, 2018, p. 322, our translation)[8].

While the author retains all rights, smart contracts would validate the use of the works. In general, using blockchain records for transfers enables the traceability of the entire licensing and assignment chain. Since all actions are recorded in an immutable and permanent sequence of blocks, "[...] a cadeia de informações de propriedade pode ser sempre rastreada" (Tam, 2019, p. 219, our translation)[9].

Beyond the direct use of blockchain records, there is a range of proposals aimed at associating NFTs with copyright management. Drawing a comparison between the release of an NFT containing a new artwork by an artist and the printing of art reproductions for sale as numbered and signed copies, Pesserl (2021) concludes that the purchaser of either acquires ownership of the physical item but not the copyright. Thus, using NFTs for the commercialization of visual artworks presents advantages, particularly in a market that generally operates under the logic of a publisher.

> [...] o qual será o único responsável pela circulação da obra; [tem-se, assim,] um único titular, uma única obra, um único comercializador. Tanto o fã interessado naquela edição única quanto o investidor interessado em especular podem adquirir tais ativos para si, e o artista e seu editor são compensados (Pesserl, 2021, p. 257)[10].

The author notes that this model would require adjustments for application in the music market, as producing a phonogram, the final product for commercialization, involves multiple authors, as previously discussed. In conclusion:

> [...] a tokenização das obras e fonogramas cominada com *smart contracts* para atribuição de direitos de uso [...] oferece o acesso às receitas recorrentes da exploração direta dos direitos patrimoniais sobre obras e fonogramas […] (Pesserl, 2021, p. 290)[11].

Such an approach would eliminate intermediaries, thereby reducing transaction costs.

Similarly, Guadamuz (2021) analyzes NFT applications in copyright management. One premise the author adopts is that an NFT's characteristics are defined by its associated smart contract. Based on this, NFTs could serve multiple aspects of copyright: (1) assignment of copyright, allowing the author of a work to transfer ownership to a buyer; (2) rights registration,

8 Original: "Each author could then allow some uses under exclusive licenses if and when appropriate, and then use blockchain technology to license mass uses on a non-exclusive basis" (Bodó; Gervais; Quintais, 2018, p. 322).

9 Original: "[...] the chain of ownership information could always be tracked" (Tam, 2019, p. 219).

10 Translation: "[...] who will be solely responsible for the distribution of the work; [therefore,] there is a single owner, a single work, a single distributor. Both the fan interested in that unique edition and the investor interested in speculation can acquire such assets, and the artist and their publisher are compensated" (Pesserl, 2021, p. 257, editorial translation).

11 Translation: "[...] a the tokenization of works and phonograms combined with smart contracts for the assignment of usage rights […] offers access to the recurring revenues from the direct exploitation of economic rights over works and phonograms […]" (Pesserl, 2021, p. 290, editorial translation).

provided there is a verifying authority (NFT marketplaces themselves could play this role), though, as the author notes, “Lixo entra, lixo sai, só porque existe uma reivindicação de titularidade registrada em uma *blockchain*, não significa que ela seja verdadeira” (Guadamuz, 2021, p. 1375, our translation)[12]; (3) (3) licensing, since, in theory, smart contracts could embody any type of agreement, and if a license is understood as a legal document granting the licensee permission to perform certain actions on a copyright-protected work, then such a license could be represented by an NFT; and (4) royalty control, which would be the most beneficial application of NFTs, as

> [...] as características intrínsecas de capacidade de pagamento dos *smart contracts* permitem que os autores recebam de forma imediata pelos seus trabalhos [...] (Guadamuz, 2021, p. 1376, our translation)[13].

In terms of royalties, another possibility described is the inclusion of automatic payment clauses in the event of a work’s resale, specifying a given percentage of the transaction. Each time the token associated with the work changes hands, the author would automatically receive payment.

In general, given the specificities of blockchain technology and its related components (smart contracts and NFTs), copyright benefits from: (a) the guarantee that each record is unique, as determined by the hash associated with its creation; (b) the fact that the exact moment of registration is determined by a validated timestamp (trusted timestamping); and (c) the fact that a record’s traceability, as well as any subsequent transfers, can be controlled through smart contracts. This not only ensures the accurate and automatic payment of royalties and other fees but also allows for tracking co-authors, recording the chain of rights holders (and types of rights), accounting for the number of copies sold by the rights holder, and thus combating counterfeiting, among other benefits.

Computer Program

Although the protection of a computer program may, in specific cases, involve patents[14] (when a technical solution to a given problem is present) or industrial design protection (when the interface generated is protected), the source code of a program is exclusively subject to copyright protection (Brasil, 1998b). In this regard, Passos (2019) examines the possibility of registering computer programs on a blockchain and the feasibility of such registrations being adopted by the INPI. Once legal feasibility is established, the author proposes using blockchain to record information related to the code (hosted off-chain, i.e., outside the blockchain), with

12 Original: “Garbage in, garbage out, just because there is an ownership claim written in the blockchain, it does not mean that it is true” (Guadamuz, 2021, p. 1375).

13 Original: “[...] the built-in payment capability of the smart contract allows authors to receive immediate payment for their work [...]” (Guadamuz, 2021, p. 1376).

14 This protection is granted via Computer-Implemented Inventions (CII), according to Brasil (2020).

the system maintained by INPI itself (Passos, 2019, p. 49). According to the author: “As tarefas de validação do usuário, checagem dos dados do programa de computador e resumo *hash* do código fonte passarão a ser feitas automaticamente na plataforma […]” (Passos, 2019, p. 50)[15]. In this model, blockchain would be responsible for “[...] um registro seguro do controle de versionamento de cada edição feita pelo usuário e/ou terceiros que estejam participando de seu código-fonte” (Passos, 2019, p. 51)[16].

Industrial Property

As previously noted, while it is the State’s role to grant protection for creations falling under industrial property, merely recording a patent application, trademark application, or similar asset on a blockchain does not guarantee the corresponding exclusivity.

In general, industrial property protection mechanisms include patents (for inventions and utility models), industrial designs, geographical indications, and trademarks—all regulated by Law No. 9.279 of May 14, 1996, known as the Industrial Property Law (*Lei da Propriedade Industrial* – LPI). Trade secrecy, which is not a form of exclusivity granted by the State, will be analyzed separately.

Patents

Regarding patents, Bian (2021) proposes a system based on a private, or permissioned, blockchain[17], where user access (for applicants and examiners) would be granted only after prior authorization from an external authority. In this blockchain, the respective national or regional patent offices would serve as the nodes responsible for consensus-based validation. All operations related to the patent examination process would be recorded, regardless of the country of filing. Applicants and examiners would have access to the blockchain and, consequently, to the deposited and under-review documents, which would be stored in a decentralized database external to the blockchain.

Similarly, Gunasekara (2022) proposes the use of this type of blockchain, with principles similar to those suggested by Bian (2021), but implemented on the Ethereum blockchain to enable extensive smart contract support. In this proposal, however, the author focuses on problems involving the filing and management of patents on a global scale. Integrating patent applications and granted patents into a single system, validated by participating nodes (national and regional offices), would facilitate prior art searches, record ownership transfers, and more (Gunasekara, 2022, p. 339).

15 Translation: “User validation tasks, verification of computer program data, and hashing of the source code will be performed automatically on the platform […]” (Passos, 2019, p. 50, editorial translation).

16 Translation: “[...] secure registration of version control for each edition made by the user and/or third parties involved in the source code” (Passos, 2019, p. 51, editorial translation).

17 Unlike permissioned blockchains, permissionless (public) blockchains allow any user to create an address and interact with the system. The latter type is generally used in cryptocurrencies.

Following a similar logic, and with a focus on managing (particularly negotiating) already granted patents, Hu (2022) presents a system in which holders of granted patents would upload the patent directly onto the blockchain, meaning the information would be on-chain. Verification of whether an identical patent had already been filed would remain the responsibility of national offices; however, in this case, these offices would not necessarily serve as validator nodes, as validation could be performed by the network's users themselves.

Conversely, Li (2022b) proposes a storage structure for information on patents that have not yet been disclosed. Sensitive data contained in the documents (owner, inventor, etc.) would be stored on-chain, while non-sensitive data, namely, the patent application itself, would be stored off-chain in a centralized, fragmented database. A hash of this non-sensitive data would also be generated and stored on-chain.

Loke (2019) describes a system for registering new inventions based on the use of conceptual graphs. Instead of describing the invention through text-based claims, these claims would be documented using conceptual graphs, which capture the concepts contained in the text along with their relationships (Loke, 2019, p. 642). Once the graphs were produced from the claims, their corresponding hashes would be generated and stored on a blockchain.

Denter (2022) presents a systematic review of blockchain's potential uses in patent portfolio management. The author analyzes seven dimensions that constitute such a portfolio: Generation (of knowledge for patent production), Enforcement (legal enforcement of patent rights), Exploitation (commercial use of patents), Organization (how patents are structured within the institution), Culture (the institutional culture surrounding patent production), and Intelligence (deriving insights from existing patents). The seventh dimension is the Portfolio itself, whose strategic management defines its composition; this central dimension would not benefit directly from blockchain but rather indirectly.

In the Generation dimension, blockchain could be used for timestamping results from R&D activities, particularly in open innovation contexts, ensuring a verifiable record for the first creator. In Enforcement, blockchain could support "defensive publication," where patenting costs are prohibitive and the company opts to publish an invention to prevent competitors from patenting it; this would also require timestamping.

In the Exploitation dimension, blockchain would enable "decentralized patent marketplaces," allowing direct negotiation between buyers and sellers without intermediaries. The Organization dimension could support new organizational models, such as expanding collaboration networks at lower cost by eliminating a central managing entity, enabling free information exchange between academia and industry without third-party mediation. In the Culture dimension, blockchain could encourage participation in idea-generation processes: for companies with distributed headquarters, blockchain-based idea or task registration could facilitate monitoring, increase competitiveness between teams, and raise the likelihood of generating new patents (Denter, 2022, p. 12).

Finally, Bamakan (2022) considers the use of NFTs to represent patents as digital assets. A patent could be registered on a blockchain in the form of an NFT, simplifying

negotiation, whether for assignment or licensing, by enabling ownership traceability and automatic royalty payments. The author proposes a five-layer structure: (1) storage (on-chain or off-chain) of patents; (2) authentication of NFT-linked patent holders via smart contracts; (3) verification of deposited patents, supposedly by experts designated by patent offices; (4) asset management through blockchain; and (5) negotiation through available marketplaces.

Industrial Designs

Regarding industrial designs, while the search retrieved no documents (see **Table 1**), this form of protection has been using blockchain for some time. For example, in 2021, two major search platforms, TMview (for trademarks) and DesignView (for industrial designs), both managed by the European Union Intellectual Property Office (EUIPO), were integrated into a single blockchain whose nodes are European offices. This integration provides access to trademarks and industrial designs while increasing the security of the records (EUIPO, 2021).

Furthermore, given the similarities in how industrial designs and patents may be transferred and recorded for various purposes, many of the applications proposed for patents are also applicable to industrial designs. These include, for example, ownership traceability, automatic royalty payments, and registration for proof of existence.

Geographical Indications

Regarding Geographical Indications (GIs) and the potential benefits of using blockchain, only one document was retrieved (Aronzon, 2019), which analyzes the feasibility, advantages, and disadvantages of this combination, both for establishing a GI and for maintaining an existing one.

Recognizing that one of blockchain's most successful applications has been in controlling food supply chains, and that a GI is based on controlling the sourcing of products from a specific geographical region, the author concludes that: "Combinação da tecnologia blockchain com smart contracts e soluções em IoT melhorariam os benefícios" (Aronzon, 2019, p. 2, our translation)[18] for maintaining and enforcing rights related to already established geographical indications. On the other hand, considering the legal requirements for establishing GIs in the United States and Europe, the author concludes that blockchain: "[..] adicionaria pouco valor para uma IG que esteja procurando estabelecer proteção inicialmente" (Aronzon, 2019, p. 19, our translation)[19].

For existing GIs, the recommendation is to use a private blockchain, with a trusted intermediary coordinating the producers. This role could be played either by the GI's producer group (GI monitors) or by the World Intellectual Property Organization (WIPO), should

18 Original: "Combining blockchain technology with smart contracts and Internet of Things solutions will enhance those benefits" (Aronzon, 2019, p. 2).

19 Original: "A blockchain application would likely add little value to the process of establishing protection for GIs" (Aronzon, 2019, p. 19).

the solution be widely adopted (Aronzon, 2019, p. 42). The advantages include collecting information for submission to GI monitors, recording certifications conducted during inspections, preventing the GI from becoming generic (thus losing its GI status), and keeping non-compliant products off the market, among others (Aronzon, 2019, p. 43).

Trademarks

Finally, within the scope of industrial property, trademark protection is addressed in Showkatramani (2019), which presents a system based on smart contracts for storing trademark-related information on a blockchain. The proposal is for a private, or permissioned, blockchain, primarily for the registration of trademarks already granted by the relevant authority. Once the trademark certificate (stored off-chain) and its metadata (registration number, filing date, registration date, classification, etc.) are entered into the proposed system, a hash of the certificate would be generated and stored on the blockchain alongside the metadata.

Deblis (2018) presents an analysis of blockchain use in trademark regulation. According to the author, despite advantages such as security, broad access, low operating costs, and ease in resolving transactions and disputes – and even if governments were to develop regulations for using blockchain in trademark rights management – lawyers would still be necessary for arguments and interpretations in disputes (Deblis, 2018, p. 378).

Lastly, it is worth reiterating the aforementioned example of the EUIPO's integration of the TMview and DesignView systems.

Sui generis

Sui generis protections, as the name suggests, apply to creations that do not fit into established categories of protection. In brief, the intellectual property rights under this classification include plant varieties (cultivares) and integrated circuit topographies. A third group within this category, genetic heritage and traditional knowledge, will not be addressed here due to its specificities.

It is worth noting that searches for these topics, in connection with the technologies discussed here, returned no results in the Scopus database. The same applies to protections for plant varieties and integrated circuit topographies. Although it is evident that both could benefit from blockchain (for prior proof) and smart contracts (for licensing and assignment control), the development of literature on such possibilities remains scarce or non-existent.

Other Types of Protection

As previously mentioned, there are forms of protection that, by their nature, are not subject to legal exclusivity. These include proprietary knowledge held exclusively by its owners and, therefore, not granted exclusivity by the state. This category encompasses trade

secrets and know-how, whose definitions sometimes overlap and may or may not be used interchangeably (Barbosa, 2003, p. 636)[20]. It is worth noting that, although such protections are not guaranteed through a formal title (such as a patent or a registration), they are partially safeguarded under the Industrial Property Law (Lei da Propriedade Industrial – LPI), which, in item XI of Article 195, classifies as a possible act of unfair competition any person who "divulga, explora ou utiliza-se, sem autorização, de conhecimentos, informações ou dados confidenciais, utilizáveis na indústria […]" (Brasil, 1996, p. 8353)[21].

Once again, although searches using the aforementioned terms – combined with part_A of the search string – returned no results on the platform used, literature on the topic can be found in open-access sources (maintaining, as stated before, the criterion of peer review).

Leite (2020) provides a brief legal analysis of existing case law regarding the use of blockchain to prove ownership of trade secrets. The authors note that, even though there is no specific legal provision concerning "[...] uso do *blockchain* como meio de prova apta a subsidiar ações judiciais decorrentes de eventual quebra de sigilo industrial […]" such a tool could be considered as atypical evidence and, therefore, taken into account in litigation (Leite, 2020, p. 1836)[22]. Furthermore, blockchain registration would fit into cases already provided for "[...] no Código de Processo Civil, na Declaração de Direitos de Liberdade Econômica e Sistema Notarial Eletrônico […]" (Leite, 2020, p. 1836)[23]. The authors further point out that, unlike Brazil, some U.S. states, as well as China and Italy, have already created or adapted legislation "[...] no que diz respeito à admissibilidade do *blockchain* como meio de prova em processos ou procedimentos judiciais […]" (Leite, 2020, p. 1842)[24].

In another investigation on the subject, Wasim (2018) advocates, among other possibilities, for the creation of a model that could be implemented on a blockchain to automatically issue an injunction in the case of a potential breach of a contract containing trade secrets. The proposal is based on using an unsupervised machine learning algorithm that would automatically trigger a smart contract, which in turn would issue the injunction or a temporary restraining order. According to the author, the machine learning algorithm operates by analyzing the significance of the detected breach, and as long as it has the potential to cause substantial harm, the smart contract would be triggered (Wasim, 2018, p. 102).

Finally, Busnello (2022) presents a method for transferring trade secrets, taking into account the issue posed by Arrow's Information Paradox. According to Arrow:

20 Barbosa (2003) analyzes the concepts of know-how, trade secret (American industrial secret), and secret de fabrique (French manufacturing secret).

21 Translation: "discloses, exploits or uses, without authorization, confidential knowledge, information or data, usable in industry […]" (Brasil, 1996, p. 8353, editorial translation).

22 Translation: "[...] the use of blockchain as admissible evidence to support legal action arising from a potential breach of industrial secrecy […]" (Leite, 2020, p. 1836, editorial translation).

23 Translation: "[...] in the Civil Procedure Code, the Declaration of Rights of Economic Freedom, and the Electronic Notarial System […]" (Leite, 2020, p. 1836, editorial translation).

24 Translation: "[...] regarding the admissibility of blockchain as evidence in judicial processes or procedures […]" (Leite, 2020, p. 1842, editorial translation).

> [...] existe um paradoxo fundamental na determinação da demanda por informação; seu valor para o adquirente não é conhecido até que ele saiba da informação, mas neste momento ele efetivamente a adquire sem custo (Arrow, 1962, p. 615)[25].

Busnello therefore proposes using a smart contract instantiated on a blockchain to transfer a given trade secret. The method is based on:

> [...] uso de Provas de Conhecimento-Nulo, operadas por *smart contract* instanciado em *blockchain*, para controle de informações apresentadas como Provas e para efetivação automática das contraprestações sinalagmáticas, com simultâneas entregas do conhecimento e do pagamento às partes contratantes (Busnello, 2022, p. 10)[26].

Technology Transfer Contracts

Given what has been discussed thus far – particularly concerning smart contracts – many aspects of the formalization, control, and execution of contracts could be carried out using such tools, especially if the smart contract is instantiated on a blockchain for proper decentralized authentication. Swanson (2014) presents a comprehensive analysis of the advantages and disadvantages of migrating contracts in general to self-execution via smart contracts.

Specifically regarding contracts involving the licensing (for use or exploitation) and/or assignment of intellectual property, the examples previously presented corroborate the real feasibility of using smart contracts and blockchains for digital validation and signature (eliminating the need for a notary), royalty control, ownership and/or authorship management, copy traceability, and enforcement of penalties, among others.

A third type of contract involving technology transfer is that of franchises. In this field, research has also been conducted to determine the feasibility of using such technologies. Baron and Chaudey (2019) present an analysis identifying several aspects in which blockchain could improve the management of this type of contract. According to the authors, supply chain management, trademark protection, security and transparency in the payment of fees and royalties, and access to reliable information are among the advantages.

A key consideration is the case where smart contracts used to manage these aspects must have access to information external to the blockchain. For this purpose, the authors highlight the concept of the oracle, a specific type of smart contract capable of retrieving external information and, therefore, potentially acting as a security vulnerability (Baron, 2019, p. 7).

25 Original: “[...] there is a fundamental paradox in the determination of the demand for information; its value to the purchaser is not known until they know the information, but at that point they have effectively acquired it without cost” (Arrow, 1962, p. 615).

26 Translation: “[...] the use of Zero-Knowledge Proofs, operated by a smart contract instantiated on a blockchain, to control the information presented as Proofs and to automatically carry out the synallagmatic counter-performances, with simultaneous delivery of the knowledge and payment to the contracting parties (Busnello, 2022, p. 10, editorial translation).

Specifically among the aforementioned advantages, one of the areas that would benefit most from blockchain use would be the franchise's supply chain. The cited advantages include eliminating intermediaries (thus reducing costs), automatic execution of commercial agreements (contractual clauses), auditability of completed transactions, and validation of results by all network participants (franchisees), among others (Baron, 2019, p. 13).

CONCLUSION

The emergence of blockchain has enabled a broad range of applications beyond cryptocurrencies – applications which, unlike the latter, often address domains that already had existing solutions but now benefit from new perspectives.

This article reviewed scientific publications to present different solutions and approaches for using blockchain – and, by extension, related technologies such as smart contracts and NFTs – in the protection and transfer of various intellectual property assets.

Among these, copyright-related solutions appear the most promising for implementation. Three main aspects were identified: registration and protection, transfer, and control of territoriality. Most proposals involve recording hashes and metadata of digital files linked to the works, with the specific approach varying by industry (music, film, books, etc.). Factors such as the feasibility of placing the file on-chain, the use or avoidance of watermarks, and the need for author anonymity may influence the chosen solution. In this context, NFT-based proposals stand out for their straightforward association between the protected file and its linkage to a smart contract managing the NFT.

Trademark registration and transfer processes follow principles similar to those of copyright. Recording trademark-related information (hashes, metadata, or the trademark itself) facilitates proof of prior use, ownership traceability, and automated payments – direct applications of blockchain and smart contracts. Similar reasoning applies to computer programs, particularly regarding their source code.

For patents – and, to some extent, industrial designs – proposals range from registering sensitive information during the creation phase to controlling the application process up to the grant stage, enabling document traceability (regardless of country of origin) and supporting portfolio management in its various dimensions. Other assets, such as integrated circuit topographies, plant varieties, and geographical indications, show little or no proposed solutions in the literature, leaving space for new approaches, whether to validate or challenge the application of blockchain in these cases. A similar observation applies to trade secrets, despite existing analyses and proposals.

Contracts, in contrast, appear particularly promising. While many contractual clauses can be deterministically translated into smart contracts for automatic execution, some still require negotiation due to ambiguities in wording or information asymmetries between the parties.

Although all the solutions discussed here are technically feasible, their adoption depends on more than market acceptance. Legal issues, which vary between jurisdictions, as outlined in the TRIPS Agreement, mean that immediate implementation is often not possible. Amendments or the creation of specific regulations, accepted by countries participating in various intellectual property agreements, are essential.

Finally, blockchain is not a universal solution. Even if a blockchain-based approach can be developed for numerous applications, not all will achieve market recognition or outperform existing systems. Established solutions that are demonstrably secure, robust, and comprehensive should remain in use until they no longer meet their intended purpose or until superior alternatives, whether or not blockchain-based, are identified.

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