I Rest My Case! The Possibilities and Limitations of Blockchain-Based IP Protection

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Abstract. We have identified, mapped and discussed existing research on Blockchain-based solutions for intellectual property (IP) protection, an investigation that emerged from a case in antibody production for scientific and medical applications. To that end, we have performed a systematic literature review and created an instrument that classifies the contributions according to the materiality of the object they protect (from immaterial to physical), the type of protection (authorship notarization or prevention of illegal use) and the type of research (conceptual or empirical). Our results can be used to understand which avenues to pursue in the effort to create a new generation of more effective technology-assisted IP protection systems, a priority for 152 signatory countries of the patent cooperation treaty.

Keywords: Antibodies · Blockchain · Intellectual property

1 Introduction

The global market for antibodies for research was valued at USD 2.52 billion in 2016 and it is anticipated to progress at a Compound Annual Growth Rate (CAGR) of 6.1% over 2018–2025. Antibodies are high-value proteins produced in living cells and vastly used for scientific research, medical diagnostics, and advanced therapies, namely as biopharmaceutical drugs. They originate from two sources: native and in vitro. An animal, such as a rabbit, inoculated with a vaccine X will typically respond by producing Anti-X antibodies. These can either be recovered from the blood of the animal (native source, resulting in polyclonal antibodies (pAbs)) or they can be processed with advanced methodologies to collect the genetic (DNA) information that allows in vitro production

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(in vitro source, resulting in monoclonal antibodies (mAbs)). Biopharmaceutical and pharmaceutical companies are heavily dependent on the use of both, pAbs and mAbs for R&D on innovative treatments for cancer and other chronic diseases, which has dictated a tremendous market traction. [37]. Monoclonal antibodies (mAbs) account for the leading share in this market. The in vitro molecular processing involved in their production enables the identification of very precise and unique genetic recipes for antibodies with specific capabilities (e.g. interacting with and killing a cancer cell). These recipes are nothing more than instructions in the form of a DNA sequence (a string of letters, A, T, G and C), that can be given to specialized living cells to produce the ultimate antibody molecule of interest. Importantly, this unique mAb recipe, becomes a high-value intellectual asset that requires special protection, since it can be used for replication and commercialization at an industrial scale. Patenting is a common route [11], but it can be very complex and costly, especially considering that the requirements needed to confer the patent may differ according to the countries in which it is applicable [22]. Additionally, patent enforcement often means expensive and long legal suits.

Thus, our research question is:

RQ: Are there Blockchain-based techniques suitable for the protection of immaterial intellectual assets, such as antibody recipes?

To investigate this issue, we started with a systematic literature review (SLR), which allows identifying, evaluating, and interpreting available research relevant to a topic area or phenomenon of interest, such as the summary of evidence concerning a given technology [9]. Our key concepts are (1) intellectual property (IP) and (2) Blockchain.

Intellectual property results from the work of the mind or intellect, which may be an idea, an invention or a process [34]. Depending on the adopted form of legal protection, the conferred rights will differ. Available forms are (1) patents, (2) trademarks, (3) copyrights, and (4) trade secrets [18], briefly described below:

- The patent is an exclusive right granted to an invention (product or a process), which prevents it from being commercially made, used, distributed, imported or sold without authorization of the patent owner [35]. It has a duration of 20 years and it is territorial, i.e., the rights are only applied in the country or region where the patent was granted, in accordance with the laws of that territory [35].
- Trademarks are used to distinguish companies, products or services by means of a word or symbol [18]. Legal owners can prevent its use by others within specific commercial limits. The trademark rights are valid for 10 years but may be renewed indefinitely [40] while the trademark is properly used and enforced [18]. It can be applied at the country or region level, or at the international level, depending on the type of registration [40].
- Copyright is an exclusive right assigned to the author or creator of a e.g. literary, artistic, musical, software products [18]. For content to be copyrightable it needs to (1) be permanently registered in some medium (e.g. paper, computer), (2) be original, and (3) exhibit creativity [18]. Copyright offers financial protection, enabling authors to license the use of their work for a fee, and also moral protection of non-economic interests [32], such as attribution or reputation. It has a finite duration that depends on the laws applied in the country/region of its use [18].

- Trade secrets are, as the name implies, secrets (e.g. formulas) that afford commercial or technical advantage [18] to a business because they are not known or easily discovered by observation [39]. Content may or may not be patentable, but if it becomes public the holder may lose all competitive advantage that the trade secret provides [18]. It has no legal protection and lasts only until discovered [18].

Blockchain is a technology originally introduced in the context of Bitcoin, to avoid the double spending of digital money, but whose underlying mechanisms have proven interesting to multiple areas where trust is a key concern [38]. This stems from the fact that transactions are recorded on a distributed, immutable, tamper-proof ledger, that is inherently auditable. Additionally, Blockchains can store and enforce smart contracts – pieces of code that are executed automatically once predetermined conditions are met – further reducing uncertainty and promoting confidence among stakeholders [30]. In the scope of our research we will focus on existing uses of Blockchain for the protection of intellectual property.

The remainder of this paper is structured as follows. Next, we describe the methodology, detailing how we obtained the data, then we present its analysis. Section 4 draws on the content of the identified papers to address the benefits, challenges, and practical applications of Blockchain-based IP protection. Section 5 maps extant research using a specially devised instrument that enables the discussion. The conclusions summarize our work and point out limitations.

2 Methodology

Our systematic literature review follows the structure defined by Webster and Watson [26]. Our goal is to identify and map relevant research about the use of Blockchain-based IP Protection. We selected the databases Science Direct (SD) and EBSCO, due to their wide coverage, complemented by AISEL for a focus on the Senior Scholars' Basket of Journals [36]. The paper search was made on the first and second weeks of November 2018. Originally, we chose the keywords "Blockchain" or "distributed ledger technology" (DLT) combined with "intellectual property" which are directly derived from the scope of our research. However, preliminary test searches in Google Scholar suggested the additional inclusion of "copyright" and "digital rights management" for the relevant hits they surfaced. The inclusion criteria were conference and journal papers, in English, published since 2008, given the fact that this was the year of publication of Nakamoto's article on Bitcoin, considered the first successful implementation of Blockchain technology [20]. Figure 1 illustrates the search process.

A full text search returned a total of 1518 hits (270 duplicates) on the selected set of databases. To narrow down the results, a second round was conducted using the same keyword combination, but constrained to title, keywords, and abstract. A total of 83 results were obtained at this stage. After eliminating six duplicates, our set was reduced to 77 articles. The date range for this subset is from 2013 to 2018.To increase validity and decrease biases, we used researcher triangulation [3, 7], in which two authors separately analysed the abstract of the papers and classified their relevance as (Yes/No/Maybe). We made final decisions on the "Maybes" in a discussion. As a result, 57 non-relevant

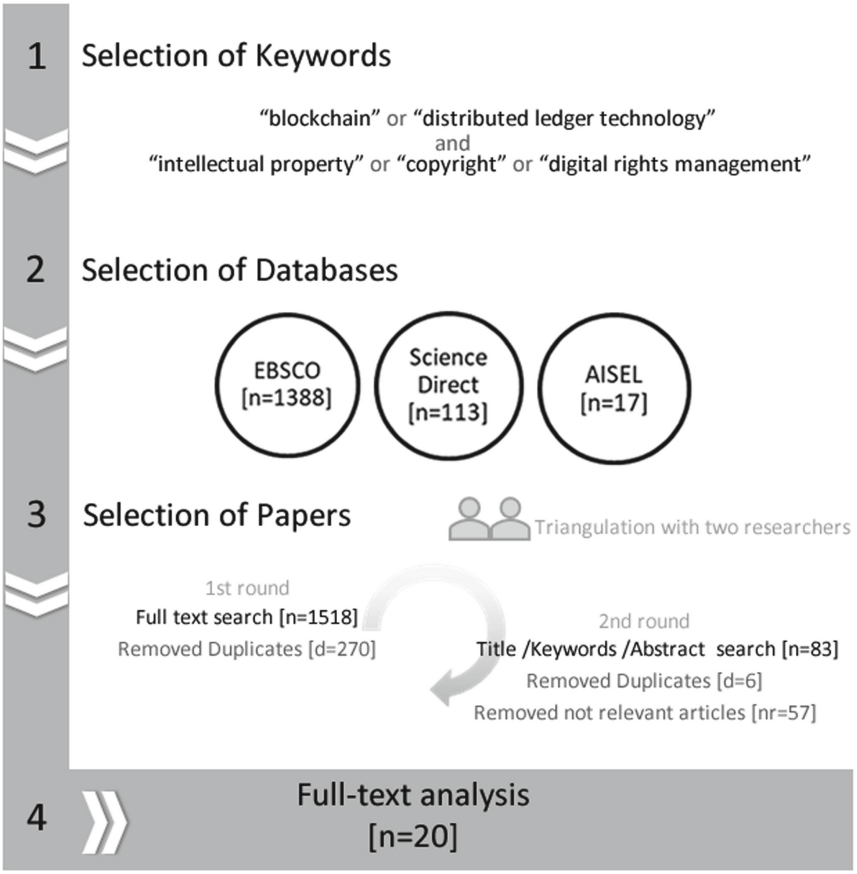

Fig. 1. Systematic literature review approach

articles were discarded and 20 remained to be analysed in-depth, by reading the full text, with the aim of extracting information about the use of Blockchain for intellectual property protection.

3 Data Analysis

The papers selected for in-depth analysis have been classified in terms of year of publication, type of research (conceptual - C, empirical - E), object of protection (e.g. music, images, software), and type of protection discussed (Authorship Notarization - AN, Use Authorization - UA). Articles that evidence the use of Blockchain for the sole purpose of authorship attribution are marked AN. If the level of protection effectively prevents illegal use or dissemination of the object, then the articles are marked UA. For every article, a brief description of the role of Blockchain was included. Table 1 presents the classification of the 20 articles analysed in-depth.

Table 1. Classification of the reviewed papers

ID	Ref	Blockchain use	Type of object	Type of protection	Year	Type of research
1	[19]	Registration of creative work, namely orphan work. With storage, dissemination, and transfer of information about copyright objects and their right holders	Creative work	AN	2017	C
2	[1]	Conception of a new ecosystem where it is possible to identify the authors, track protected content (stream), and assign a fair remuneration to the artists. The authors suggest that smart contracts could allow music royalties to be administered transparently and almost instantaneously	Music	UA + AN	2018	C
3	[2]	Normative analysis of key Blockchain technology concepts from the perspective of copyright law. Analyzes in detail the legal issues related to smart contracts and private ordering, copyright registrations, the legal regime of DRM, and fair remuneration	Digital	AN	2018	C
4	[4]	Establish ownership of the copyright, but it also helps to enforce rights (e.g. artificial intelligence could track unauthorized use on the internet, this information would be passed on to creators who could thus contact the infringer directly)	Digital	AN	2018	C
5	[5]	Analysis of the impact of blockchain on intellectual property law, namely in the registration, management and enforcement of IP rights. The authors state that Blockchain will be able to help to overcome the IP register in different legislations and dealing with different procedures	Generic	AN	2018	C
6	[6]	Analysis the possibilities of Blockchain to serve as an institution of property, and how Blockchain applications may or may not replace some aspects of legal norms and property rights	Digital	AN	2017	C

(*continued*)

Table 1. (*continued*)

ID	Ref	Blockchain use	Type of object	Type of protection	Year	Type of research
7	[8]	Analysis of impact in the music industry, such as, benefits, automating payments of royalties (combining streams with smart contracts), transparency and data protection and the existing, and compliance with legislation	Music	UA + AN	2017	C
8	[10]	Conception of a decentralized peer-to-peer software license validation system using cryptocurrency Blockchain technology. Licenses are validated with a unique license key that cannot be copied, reused, or regenerated. This key links the user and the device to the license	Software	UA	2018	E
9	[12]	Description of a Blockchain as a service (BaaS) architecture for DRM business models. Content is encrypted and stored in a centralized database. The rights confirmation and DRM assets consumption are made with Blockchain. Access to the data with tamper-resistant copyrights protection, digital currency for content consumption payment	Digital	UA + AN	2018	E
10	[27]	Description of a Blockchain-based scheme for digital rights management, with two isolated Blockchain application interfaces, to store plain and cipher summary information of original and DRM-protected digital content	Digital	UA + AN	2018	E
11	[15]	Analysis the main transformations and challenges that the record industry can face with Blockchain technology. Improve transparency, availability of copyright data and facilitate the near-instant micropayments for royalties	Music	UA + AN	2018	C
12	[16]	Conception of a smart contract for MANAGING digital reuse rights of research data, recording the information of the author and the conditions established for the reuse of the work	Research data	AN	2018	E

(*continued*)

Table 1. (*continued*)

ID	Ref	Blockchain use	Type of object	Type of protection	Year	Type of research
13	[17]	Analysis the impact of Blockchain on innovation in Scotland's digital design industries. Blockchain can support creative endeavour by enabling more autonomous and flexible IP management systems	Digital	AN	2017	C
14	[21]	Focus on legal aspects related to Blockchain under the copyright sphere. The role of the Blockchain in the distribution of copyrighted works in the digital realm	Generic	AN	2018	C
15	[23]	Analysis the possibilities of use and the importance of Blockchain and smart contract for attorneys	Generic	AN	2018	C
16	[24]	Adequacy of traditional ideas about property law in the context of digital assets, namely the cryptocurrency Bitcoin	Bitcoin	AN	2017	C
17	[25]	Possible use cases of IP management of Blockchain technology. Blockchain can create an immutable record of authenticity, which may include ownership, evidence, publication, and first and genuine use	Generic	AN	2018	C
18	[28]	Examination of Blockchain technologies in the "creation of proprietary digital art markets in which uncommodifiable digital artworks are financialized as artificially scarce commodities"	Digital art	AN	2018	C
19	[29]	Outset of a Blockchain-based solution for digital image rights management scheme. With Internet misuse detection based on watermark	Digital	AN	2018	E
20	[31]	Conception of a Blockchain-based scheme for an image copyright registry. A robust image feature vector is used to identify duplicate image registrations on the network where it is being used	Images	AN	2018	E

As shown in Fig. 2, the majority of papers (75%) were published in 2018 and the remainder (25%) in 2017, thus reflecting that the interest in the use of Blockchain technology for IP protection is recent and rising. Further, as seen in Fig. 3, 70% of the articles were of conceptual nature and 30% of them empirical. Considering the type of protection (Fig. 4), almost all papers addressed Authorship Notarization, in contrast to 30% of papers that indicated Use Authorization mechanisms. The analysis by type of object, more specifically the representation in a materiality continuum, will be analyzed in detail in the discussion.

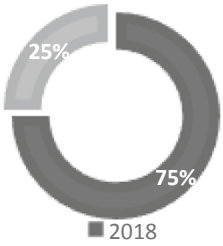

Fig. 2. Spread of papers selected by year

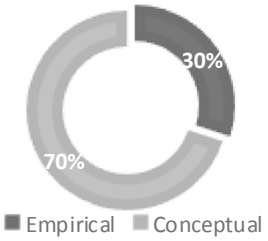

Fig. 3. Spread of papers selected by type of analysis

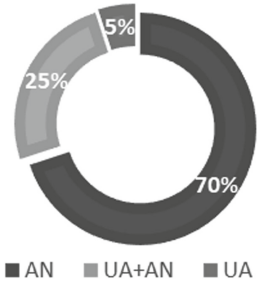

Fig. 4. Spread of papers selected by type of protection

Based on the content of the papers, in the next section we will outline the key benefits and challenges of Blockchain-based in IP protection. We will also present the use cases and examples found in the literature.

4 What the Literature Says

4.1 Blockchain for IP Protection

Several authors have verified the feasibility of using Blockchain for the registration of intellectual property. The technology supports the technical, safety, and decentralization requirements for registering copyrights [19]. It can help provide tamper-proof evidence of ownership [19]. It also brings transparency and traceability over subsequent changes, increasing the visibility and availability of that information as a "Trusted Timestamping" [21], so the products are capable of "telling their own story", since their origin to commercialization [25].

Blockchain is evolving fast, but there are major challenges to address. For example, the complexity of the technology and its promise of disruptive changes raises suspicions and concerns [4]. Negative publicity associated with some use cases, like cryptocurrencies, also affects the rate of adoption of this technology [4]. The immutable nature of the Blockchain is one of its strengths, but also raises questions, such as responsibility if wrong data is registered [23].

Blockchain-based IP registers can replace existing IP databases [6, 19]. However, it is necessary to establish criteria, perform technical tests, and keep the interests of authors and users balanced [19]. The authors go further and claim that Blockchain may be considered an institution of property, such as a legal institution, but it is too early to predict whether it will replace legal norms and property rights [6]. The work of [4] also identifies the advantages of using a Blockchain-based IP system, such as simplifying the registration process, reducing associated fees, dispensing the need to register in different jurisdictions, and self-managing of IP rights by the author, without the involvement of third parties. In summary, the literature acknowledges advantages of Blockchain for IP registration, but cautions that it is not yet proven that it will be sufficient for the effective protection against illegal use of the object.

Regarding the use of Blockchain in the context of IP protection, the literature identifies some concerns, such as, where the content will be stored: in the Blockchain proper or "off-chain" [21]. In the latter case, some argue that using the Blockchain as a mere time-stamping service for "off-chain" content cannot guarantee reliability [21]. It is suggested that the use of Blockchain may disrupt the existing creative distribution networks, with [17] questioning how market will react to increased copyright control. In a nutshell, literature points to some challenges inherent to the Blockchain technology, but also raises important issues related to implementation and market acceptance.

4.2 Smart Contracts Role for IP Protection

More recently, smart contracts became a central feature of Blockchain technology [5]. These software-based contracts enforced by the Blockchain can include specific conditions for sale or licensing [2, 4]. Moreover, they enable property rights to be verified automatically [19]. Their main advantages are the possibility of control over the distribution [21], exploration of copyright-protected content [2], rewarding of the authors [1, 2, 8, 21], and enabling of near-instant micropayments [15]. Smart contracts may also allow substantially lower transaction fees [2, 15] for both, rights-owners and users [21], without the need for intermediaries [1, 8, 15]. Nevertheless, complete disintermediation is seen by some authors as somewhat challenging [15], not desirable, or even impossible to occur in some fields [2]. It is argued that, in some cases, the intermediates may continue to be necessary [1], for example, to provide seed capital and help in negotiations. Some suggest that their roles may change [15]. Generally, the authors of the analysed papers highlight the advantages of using smart contracts, namely in the protection and exploitation of copyright-protected content, however, there is no consensus of the role to be played by intermediaries in the future, if any.

4.3 Legal Support for Blockchain-Based IP Protection

Intellectual property law has emerged as a way to prevent unauthorized distribution of creative expressions due to easy mechanical, technological, and digital reproduction [28]. Some papers have researched the articulation of Blockchain with traditional copyright law [19]. In Bodó and Quintais we can find a legal analysis of the assurances granted to technological protection measures (TPM), rights Management Information (RMI), and digital rights management (DRM) according to the international copyright law, and, in certain aspects, according with the civil law tradition of authors rights (European Union) and common law copyright (United States). It also identifies the copyright domains in which the implementation of the Blockchain can be promising and challenging: smart contracts and private ordering, copyright registries, the legal regime of DRM and fair renumeration. Blockchain-based IP protection lacks legal support and some work needs to be done in order to facilitate "user's trust in Blockchain records and their good faith usage of copyrighted works based on them need to be introduced (…) as well as the status of Smart contracts and their legal consequences" [21]. It is necessary to clarify, in legal terms, the roles of online intermediaries, and define the jurisdiction and the choice of law that will involve the Blockchain since there is no centralized management and it can be distributed across the world [23]. It is evident in some of the papers that we analysed the concern with the impact that Blockchain will have on the current law and with its ability to meet the necessary legal requirements.

4.4 Blockchain-Based Solutions for IP Protection

Most papers in our literature review briefly mention examples of Blockchain-based systems or algorithms; however, only six provide an in-depth description of empirical solutions. The full list of examples, mentioned in the 20 papers we analysed, is presented in Table 2.

Half of the platforms in Table 2 are focused on the music industry. They enable registration of authorship and the fair remuneration for the use of the content. Of all the examples, only Ascribe is no longer available, and Blockai was rebranded as Binded. Next, we present the only six Blockchain-based systems that are discussed in-depth in the literature.

To prevent software piracy and preserve the rights of software vendors, Litchfield and Herbert have developed a Blockchain application, called ReSOLV [10]. It is a peer-to-peer software license validation (SLV) system that enables "software developers to protect copyrighted works" and prevents software interception and intrusion by malware. The operation is transparent to the user, with the license information being read from the Blockchain when the software is run.

In [12, 13], and [29] we can find the description of the design and implementation of a "Blockchain as infrastructure service for DRM business model", called DRMChain. This system stores the copyright information and enables the remuneration of authors in digital currency. Users can access digital content (e.g. videos, images), and if they do not have a license, they are redirected an acquisition and payment page. The latter is made directly to the author [12]. The protected content is encrypted [13] and uses a watermark mechanism for image data to avoid illegal use inside the blockchain [29].

Table 2. Examples of Blockchain-based IP Protection platforms mentioned in the papers

Platform	Ref.	Blockchain use	Object	URL
Ascribe	[17, 19]	Ascribe is no longer available. CoalaIp (protocol for intellectual property licensing) and BigChainDb (Blockchain database) resulted from the experience with this platform	Digital art	https://www.ascribe.io
Open music initiative	[1]	Open-source protocol for the uniform identification of music right-holders and creators	Music	http://open-music.org
Choon	[5]	Music streaming service and digital payments ecosystem	Music	https://choon.co
Blockai (rebranded as Binded)	[4, 19]	Blockchain solution for copyright registration and monitoring of images on several sources	Images	https://binded.com
Ujo	[5, 8, 15]	Open platform built on Blockchain technology, connecting music artists and fans. Uses smart contracts for agreements and payments	Music	https://www.ujomusic.com
Mycelia	[8, 17]	Blockchain music platform that aims to facilitate payments, collaborations, and partnerships. Ecosystem of music creators and any collaborators, publishers and distributors that might be entitled to a share of the value. It uses a creative passport that stores profile information, works, business partners, and payment mechanisms	Music	http://myceliaformusic.org
Muse	[8]	Blockchain music platform with payment management, such as royalties, music sales, merchandise and concert ticket sales. Registers copyright information and licensing conditions with smart contracts (configuration of different fees for using a song)	Music	http://www.muse.mu/
SoundChain	[8]	A Blockchain Music Ecosystem with streaming and automatic royalty payment. Users can share a link for a tune and receive a share of the royalty payment if another user listens to it	Music	https://soundchains.net

(*continued*)

Table 2. (*continued*)

Platform	Ref.	Blockchain use	Object	URL
Bittunes	[8]	A Blockchain Music Ecosystem based on music streaming with automatic royalty payment	Music	http://www.bittunes.com
Kodak one	[17]	Blockchain-based image rights management platform with royalty payments. The license is documented in a smart contract with copyright terms and conditions associated with each image	Images	https://kodakone.com
Screener copy	[17]	Blockchain-based forensic watermarking platform. Hosting, uploading and secure distribution of videos, with tracking of copies	Videos	https://www.screenercopy.com
Aventus	[17]	Blockchain-based event ticketing protocol where creators can track distribution and sales. Supports event organizers and inventory holders. Can track tickets as they travel through the supply-chain	Tickets	https://aventus.io
Monegraph	[28]	Blockchain platform to register, trade, sell and buy creative work	Digital art	https://monegraph.com
Publica	[17]	Blockchain end-to-end ecosystem for publishing that allows the author to obtain funds for the project and to distribute eBooks to Publica e-reader wallets. Automation of payments between authors and supporters	Books	https://publica.com
Synereo	[17]	Blockchain-enabled solution for content publishing and distribution, where the creator is paid whenever his/her work receives a "like" or "share"	Social media	https://www.synereo.com

Whenever new content is uploaded, it is checked whether it is a copy of existing work. This paper fails to identify limitations and states that the system is "reliable, secure, efficient and tamper-resistance digital content service and DRM practice".

In [31], a Blockchain-based scheme for copyright management is described. A robust image feature is used to prevent duplicate in the blockchain. However, there are no mentions to mechanisms for remuneration based on usage.

Finally, Pănescu and Manta used smart contracts to define the terms of reusing research data. The main goal is to ensure that authors control their research data, who accesses it (e.g. public or private) and under which terms. The end user of the research data benefits from a proof of compliance to the original work, opening an opportunity

to integrate the proposal with existing blockchain platforms. However, this blockchain-based protection and tracing of research data also requires the participation of publishers and data repositories. The latter need to allow smart contract execution and the publishers need to confirm that the terms have been met before publication [16].

5 Discussion and Outlook

On the one hand, a vast majority of studies conclude that the use of Blockchain to register IP rights has clear advantages and can replace existing IP databases [6, 19]. On the other hand, "registering" is only part of the equation, and there are still crucial questions that remain unanswered, namely: (1) if Blockchain is enough to ensure intellectual property protection of digital objects, and (2) what could be the role of the Blockchain for different forms of IP.

Considering the main forms of intellectual property protection that we discussed: (1) patents, (2) trademarks, (3) copyrights, and (4) trade secrets [16], some research gaps have been identified. Only four of the reviewed papers mention the application of Blockchain to patents and trademarks. Furthermore, Ruzakova and Grin argue that patent and trademark registration systems do not require the use of Blockchain, because they are already managed at a governmental executive level [19]. Trade secrets are not addressed in any of the papers. Thus, these areas of IP protection should be included in future research agendas.

Most articles mention some application of Blockchain for registration and protection of copyrights. Copyright has also attracted the interest of the European Parliament, where a reform was approved in March 2019. After intense debate, the modernization of the rules in current legislation must now be transposed to the internal codes of all EU members within the next two years [33]. This is the moment to address the role of emergent technologies in supporting the IP protection.

To make sense of the very different approaches to Blockchain-based IP protection identified in the literature, we have created the instrument presented in Fig. 5. It maps existing solutions and proposals according to three dimensions:

- The materiality of the object they protect, from purely immaterial (e.g. an antibody recipe), to digital goods (e.g. music or software), to physical products;
- The type of protection they afford (e.g. if the Blockchain mechanisms are used to "merely" prove authorship, or if they effectively prevent illegal use or dissemination of the protected object);
- The type of research (e.g. conceptual, discussing possibilities, or empirical, discussing implemented systems or prototypes).

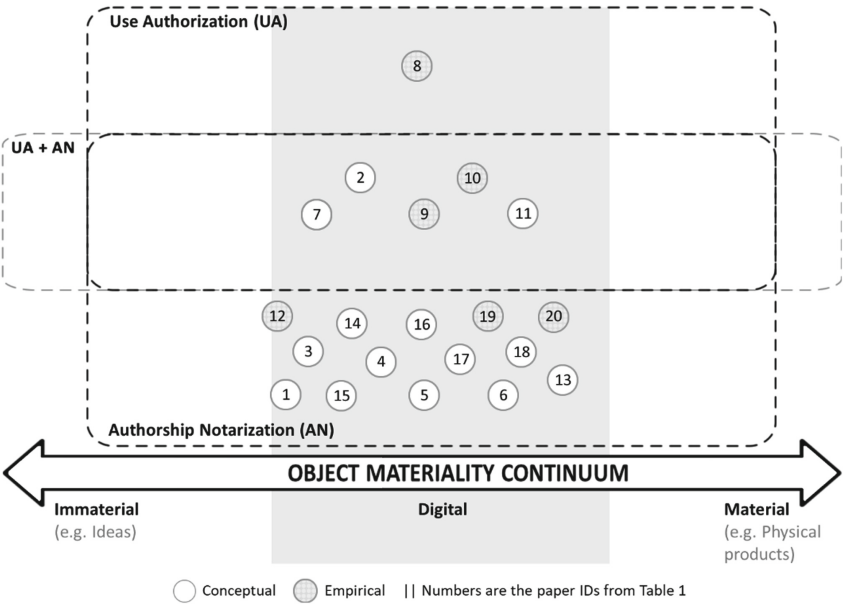

Fig. 5. Papers classified by type of object, type of protection, and type of research

The first evident observation from the use of our instrument, in Fig. 5, is that all the identified literature focusses on the digital realm. No papers discuss the Blockchain-based protection of completely immaterial forms of IP. Likewise, no papers discuss the protection of IP embedded in physical products, at the other end of the continuum. Uncovering the reasons for this bias would be a relevant topic of research. Also, specific materialities may require or enable different mechanisms for protection.

A second observation is that the majority of papers focus on some form of authorship notarization and not on mechanisms to effectively prevent illegal use or dissemination of the protected object. Important as the former is, it suffers from many of the same disadvantages of traditional forms of protection, such as patents, namely the need to resort to justice to enforce the acquired rights – an inefficient, expensive, and time-consuming endeavour, often not feasible for small and medium enterprises (SMEs).

A third observation is that the vast majority of papers are conceptual, with few discussing actual implementations. This may be due to fact that we are still at the infancy of Blockchain [14], but it also suggests that future research should strive to experiment with the technology in real cases, using pilots and proofs-of-concept.

Finally, we will discuss the reviewed literature, mapped in Fig. 5, from the perspective of our research question. Apparently, no Blockchain-based solutions exist for the effective protection of immaterial intellectual assets, of which antibody recipes (instructions, in the form of DNA sequences) are an example. Once known, these recipes can be used by unauthorized parties to manufacture and sell those particular antibodies at scale. Some proposed solutions can be adapted to provide "proof" of authorship of the recipe, but (a) enforcement would still require resorting to courts, (b) the legal value of such Blockchain-based registrations of authorship is still being debated, and (c) such

an approach does not effectively impede offenders from illegally producing and selling the antibody, as it is amply demonstrated by counterfeiters. Creating effective means for Blockchain-based protection of immaterial objects is, thus, a promising line of research.

6 Conclusion

Departing from a need to protect intellectual property related to the production of antibodies for research, medical diagnostics, and advanced therapies, we carried out a systematic literature review on Blockchain-based IP protection. We identified and mapped a set of 20 relevant articles out of an initial 1518 hits that included duplicates and off-topic instances. Selected papers were read in full and their contributions categorized using a specially developed instrument. Several promising research avenues were proposed. The analysis of specific mechanisms that could prevent the spread and illegal use of the immaterial product complemented with Blockchain technology. And the identification of the benefits/disadvantages of using Blockchain-based systems for each of the types of IP protection identified, such as patents, trademarks, copyrights and trade secrets. Essentially, we did not find in the extant literature a good answer to our research question, namely, Blockchain-based techniques that are suitable for the protection of immaterial intellectual assets, such as antibody recipes. This is particularly true if we aim at mechanisms that prevent unauthorized use. This opens several research possibilities to solve the problem posed by our case company and many others with similar concerns. No solution was identified that enabled the effective protection of an immaterial assets such as an antibody production recipe, thus validating our main line of work.

As limitations of this research we can point out the relatively limited number of databases that we searched for eligible studies, even if two of them, Science Direct and EBSCO, are major aggregators. Further, in a dynamic area like Blockchain, grey literature and market initiatives often contain recent advances not yet discussed in the academic literature.

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References

1. Arcos, L.C.: The blockchain technology on the music industry. Braz. J. Oper. Prod. Manage. **15**(3), 439–443 (2018). https://doi.org/10.14488/BJOPM.2018.v15.n3.a11. Stephan, C. (eds.)
2. Bodó, B., Gervais, D., Quintais, J.P.: Blockchain and smart contracts: the missing link in copyright licensing? Int. J. Law Inf. Technol. **26**(4), 311–336 (2018). https://doi.org/10.1093/ijlit/eay014
3. Denzin, N.K.: The Research Act in Sociology. Aldine, Chicago (1970)

4. Ensign, D.: Copyright Corner CLSR: Blockchain and Copyright. Kentucky Lib. **82**(3), 4–5 (2018)
5. Gürkaynak, G., Yılmaz, İ., Yeşilaltay, B., Bengi, B.: Intellectual property law and practice in the blockchain realm. Comput. Law Secur. Rev. **34**(4), 847–862 (2018). https://doi.org/10.1016/j.clsr.2018.05.027
6. Ishmaev, G.: Blockchain technology as an institution of property. Metaphilosophy. **48**(5), 666–686 (2017). https://doi.org/10.1111/meta.12277
7. Jick, T.D.: Mixing qualitative and quantitative methods: triangulation in action. Adm. Sci. Q. **24**(4), 602 (1979)
8. Khouri, G.: Music licensing. Licens. J. **37**(7), 25–27 (2017)
9. Kitchenham, B., Charters, S.: Procedures for Performing Systematic Literature Reviews in Software Engineering. Keele University & Durham University, UK (2004)
10. Litchfield, A., Herbert, J.: ReSOLV: applying cryptocurrency blockchain methods to enable global cross-platform software license validation. Cryptography **2**(2), 10 (2018)
11. De Luca, C., Trifonova, A.: Patent disclosure requirements for therapeutic antibody patents. Exp. Opin. Ther. Patents (2017). https://doi.org/10.1080/13543776.2017.1296950
12. Ma, Z., Huang, W., Gao, H.: Secure DRM scheme based on blockchain with high credibility. Chin. J. Electron. **27**(5), 1025–1036 (2018). https://doi.org/10.1049/cje.2018.07.003
13. Ma, Z., Jiang, M., Gao, H., Wang, Z.: Blockchain for digital rights management. Future Gener. Comput. Syst. **89**, 746–764 (2018). https://doi.org/10.1016/j.future.2018.07.029
14. Mougayar, W.: The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology. Wiley, Hoboken (2016)
15. O'Dair, M., Beaven, Z.: The networked record industry: how blockchain technology could transform the record industry. Strateg. Change **26**(5), 471–480 (2017)
16. Pănescu, A.T., Manta, V.: Smart contracts for research data rights management over the ethereum blockchain network. Sci. Technol. Lib. **37**(3), 235–245 (2018). https://doi.org/10.1080/0194262X.2018.1474838
17. Patrickson, B.: What do blockchain technologies imply for Scotland's digital design industry? In: ISPIM Innovation Conference – Innovation, The Name of The Game, Stockholm, Sweden (2018)
18. Poticha, D., Duncan, M.W.: Intellectual property-The Foundation of Innovation: a scientist's guide to intellectual property. J. Mass Spectrom. **54**(3), 288–300 (2019). https://doi.org/10.1002/jms.4331
19. Ruzakova, O.A., Grin, E.S.: Application of blockchain technologies in systematizing the results of intellectual activity. Вестник Пермского Университета. Юридические Науки **38**(38), 508–520 (2017). https://doi.org/10.17072/1995-4190-2017-38-508-520
20. Nakamoto, S.: Bitcoin: A Peer-to-Peer Electronic Cash System (2008)
21. Savelyev, A.: Copyright in the blockchain era: promises and challenges. Comput. Law Secur. Rev. **34**(3), 550–561 (2018). https://doi.org/10.1016/j.clsr.2017.11.008
22. Storz, U.: International intellectual property strategies for therapeutic antibodies. MAbs **3**(6), 596–606 (2011). https://doi.org/10.4161/mabs.3.6.17788
23. Suzuki, B., Taylor, T., Marchant, G.: Blockchain: how it will change your legal practice. Comput. Internet Lawyer **35**(7), 5–9 (2018)
24. Szilagyi, K.: A bundle of blockchains? Digitally disrupting property law. Cumberland Law Rev. **48**(1), 9–34 (2017)
25. Vella, D., Falzon, M., Cassar, T., Valenzia, A.: Blockchain's applicability to intellectual property management. Licens. J. **38**, 10–13 (2018)
26. Webster, J., Watson, R.T.: Analyzing the past to prepare for the future: writing a review. MIS Quartely **26**(2), 12 (2002)
27. Yang, D., Li, M.: Evolutionary approaches and the construction of technology-driven regulations. Emerg. Markets Financ. Trade **54**(14), 3256–3271 (2018)

28. Zeilinger, M.: Digital art as 'monetised graphics': enforcing intellectual property on the blockchain. Philos. Technol. **31**(1), 15–41 (2018). https://doi.org/10.1007/s13347-016-0243-1
29. Zhaofeng, M., Weihua, H., Hongmin, G.: A new blockchain-based trusted DRM scheme for built-in content protection. EURASIP J. Image Video Process. **2018**(1), 1 (2018). https://doi.org/10.1186/s13640-018-0327-1
30. Zheng, Z., Xie, S., Dai, H., Chen, X., Wang, H.: An overview of blockchain technology: architecture, consensus, and future trends. In: 2017 IEEE International Congress on Big Data (BigData Congress), pp. 557–564. IEEE (2017). https://doi.org/10.1109/bigdatacongress.2017.85
31. Zhuvikin, A.: A blockchain of image copyrights using robust image. Int. J. Comput. Sci. Appl. **15**(1), 33–44 (2018)
32. Copyright. https://www.wipo.int/copyright/en/. Accessed 11 Apr 2019
33. European Commission - PRESS RELEASES - Press release - Copyright reform: the Commission welcomes European Parliament's vote in favour of modernised rules fit for digital age. http://europa.eu/rapid/press-release_STATEMENT-19-1839_en.htm. Accessed 31Mar 2019
34. Intellectual Property | Definition of Intellectual Property by Merriam-Webster, https://www.merriam-webster.com/dictionary/intellectualproperty. Accessed 10 Apr 2019
35. Patents. https://www.wipo.int/patents/en/. Accessed 10 Apr 2019
36. Research - Association for Information Systems (AIS). https://aisnet.org/page/SeniorScholarBasket. Accessed 13 Apr 2019
37. Research Antibodies Market Size & Share | Industry Report, 2018-2025. https://www.grandviewresearch.com/industry-analysis/research-antibodies-market. Accessed 11 Apr 2019
38. The trust machine - The promise of the blockchain. https://www.economist.com/leaders/2015/10/31/the-trust-machine. Accessed 12 Apr 2019
39. Trade Secrets | Definition of Trade Secrets by Merriam-Webster. https://www.merriam-webster.com/dictionary/tradesecrets. Accessed 11 Apr 2019
40. Trademarks. https://www.wipo.int/trademarks/en/. Accessed 11 Apr 2019