

DETC2019-98293

**A BLOCKCHAIN PLATFORM FOR PROTECTING INTELLECTUAL PROPERTY:
IMPLICATIONS FOR ADDITIVE MANUFACTURING**

Behzad Esmaeilian

Industrial Engineering and Engineering Management
Western New England University
Springfield, MA, 01119
behzad.esmaeilian@wne.edu

Angshuman Deka

Mechanical and Aerospace Engineering
University at Buffalo, The State University of New York
Buffalo, NY, 14260
angshuma@buffalo.edu

Sara Behdad*

Mechanical and Aerospace Engineering
Industrial and Systems Engineering
University at Buffalo, The State University of New York
Buffalo, NY, 14260
sarabehd@buffalo.edu

ABSTRACT

Prior studies have already predicted that enforcement of IP on the additive manufacturing industry will not be successful due to the widespread use of file-sharing technologies, similar to the entertainment and music industry. This paper discusses the capabilities of Blockchain technology for protecting IP in the design and manufacturing area. A conceptual framework for a digital platform is defined in this paper and further, a survey study of engineering design and manufacturing students has been conducted to identify the main motivation behind developing these platforms and the types of features that should be included in Blockchain-based IP platforms for asset protection, particularly for product design. In addition, respondents provided their opinions about the type of industry that might be affected more by the threat of counterfeiting products and the role of Blockchain-based IP systems on the growth and development of innovation.

Keywords: Blockchain, Intellectual Property, Design Blueprints, Additive Manufacturing

1. INTRODUCTION

The decentralized nature of additive manufacturing (AM) provides flexibility in the manufacturing process. However, a major issue related to the products made using AM is the

protection of IP rights. AM possess a unique type of decentralized piracy where counterfeit goods can be produced easily. The 3D printer owners may buy licensed designs for 3D printing but there are chances that owners will print products protected by IP rights without obtaining the necessary rights [1]. Kietzmann et al. [2] discussed how additive manufacturing possess a challenge in stopping violation of IP rights. They discussed how an original object can be scanned and printed and the scan can be circulated for others to be used for printing. Yampolskiy et al. [3] examined how outsourcing AM production leads to issues with protecting IP rights and proposed an IP protection model for outsourcing AM printing. Kurfess et al. [4] provided a detailed discussion about the IP issues that are related to AM. They discussed how the digital files can be easily transmitted and modified raising serious IP issues which the current US patent system may not be able to resolve appropriately. The study on intellectual property conducted by Mendis et al. [5] found that 65 % of the design files uploaded online did not have any licensing scheme associated with it and thus they do not have any IP rights associated with them. Cloud manufacturing environment also faces challenges related to IP protection. Lu et al. [6] proposed strategies to prevent IP leakage from the cloud environment and mentioned that in such an environment the best way to protect IP rights is to share as minimum information as possible. Thus, it can be seen that advanced

manufacturing possesses a serious risk of IP being leaked or IP rights getting violated. Thus, there is a need for a technology that can protect the IP rights especially in the case of products manufactured using AM.

Sharing a design on a network makes it convenient for multiple entities to access, modify and use the asset. Figure 1 represents the concept of sharing a design asset in a network accessible by multiple entities. Although sharing design data on a network, such as the internet, provides the advantage of being accessible by multiple users or manufacturing equipment connected through the cloud, easy sharing of files over the internet makes it challenging to protect the IP rights.

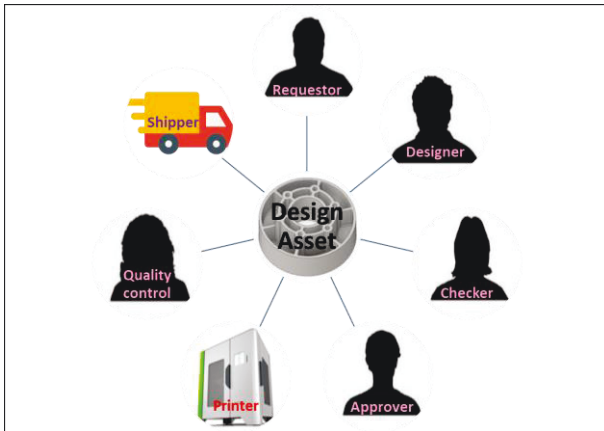


Figure 1: Design shared by multiple entities on a network. (Note: Some icons in the image are adapted from the internet).

Figure 2 represents the current situation of the IP in the design and manufacturing industry. A design asset made by a designer is accessible to different types of users. However, there are multiple situations where the designer is not compensated for his work since individual users can easily share it over the net.

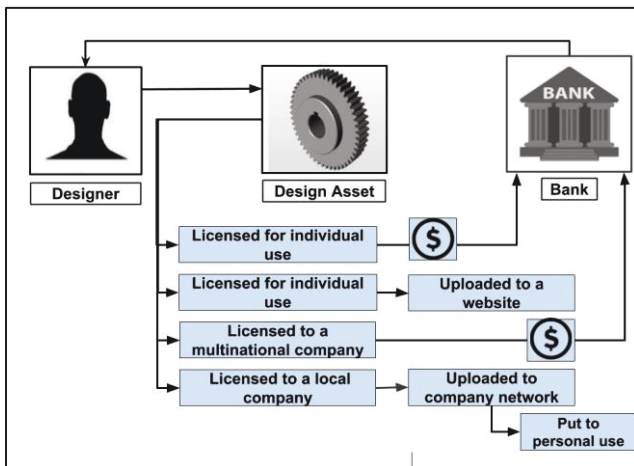


Figure 2: Current situation of IP in the design and manufacturing industry (Note: Some of the icons have been used from the internet.)

This paper discusses the concept of a digital platform built upon the Blockchain technology for protecting IP in the design and manufacturing area. A survey is conducted to seek the opinions of future designers on the use of this technology and the capabilities that it offers for protecting design assets. The contribution of the paper resides in proposing a conceptual framework for a digital platform that can address IP issues in the additive manufacturing industry.

The emphasis is put on the additive manufacturing industry for three main reasons: (1) AM is more prone to the IP issues due to the potential access of the public to 3D printing capabilities, (2) 3D printers can be connected to cloud-based digital platforms and have unique identifiers registered on digital platforms which makes verifying and monitoring more practical, (3) existing cloud-based business models in AM industry open the door for monetizing Blockchain platforms and facilitating the development of them.

The rest of this paper is organized as follow. Section 2 reviews the available literature. Section 3 discusses the elements of the proposed Blockchain platform. Section 4 describes the questionnaire and the results obtained from the survey. Finally, Section 5 discusses the conclusions and provides directions for future research.

2. BACKGROUND

This section discusses the three key features of future manufacturing systems and the Blockchain concept which can be implemented for maintaining IP rights in future manufacturing systems.

2.1. Three key features of future manufacturing systems

Three key features of future manufacturing systems are decentralized manufacturing, global manufacturing and on-demand production, and digital manufacturing.

In a *decentralized manufacturing* environment, a product is produced at a location as close as possible to the customer, making the process sustainable. This helps to fulfill the local customer requirements, reduce delivery time and lower logistic cost [7]. Product personalization, a key demand of customers, combined with market fluctuations can be efficiently handled by decentralized manufacturing environment [8]. Mourtzis et al. [8] demonstrated this through their work where they proposed an optimum manufacturing network for producing customized CNC machines. In similar lines, AM can play an important role in a decentralized manufacturing environment as designs and requirements can be transferred digitally reducing logistic cost and impact on the environment [9]. Another reason for future manufacturing to move towards decentralized manufacturing as it not only helps in production but also helps in regional growth and social well-being of people

where the manufacturing environments are established, especially in developing countries [10].

The concept of *global manufacturing* has been developed significantly in recent years due to the reduction in transportation and communication cost resulting in transnational production networks. This created an opportunity for the developing nations to be a part of the production chain, where instead of producing the entire product they can produce certain parts in the production process [11]. Asian markets have played a key role in the development of global manufacturing in recent years which has led manufacturers to make the products near the end user location resulting in a decrease of manufacturing and logistics cost. In addition, research and development in global manufacturing resulted in new product development keeping the customer in mind and developing mass customized products [12]. Global manufacturing can be supported by additive manufacturing which can cater to customized on-demand production resulting in cheaper products for consumers by utilizing limited resources [13]. The high expense of obsolescence cost of parts in the inventory makes AM a better candidate for on-demand production [14]. Peres et al. [15] in their work discussed how AM can support the spare part demand and would limit the number of parts stored for future use. Reeves [16] discussed four business which did not have the concept of inventory, eliminating the need for warehouse and distribution. Instead, it produced goods on demand in-house or at third-party sites and shipped directly to the customer.

Digital manufacturing is a rapidly growing technology which can reduce product development time and cost. In addition, it can help improve product quality and respond to market changes [17]. Digital manufacturing enables the production process directly without the need for process planning and can be used for directly making final products needed by a consumer [18]. Digital manufacturing can also play an important role in advanced engineering concepts like hybrid reconfigurable systems. Andrisano et al. [19] proposed a method to optimize and design a hybrid reconfigurable system by using virtual prototyping. AM is considered as a key digital manufacturing technique and has undergone significant development in recent years [20].

With the advancement and integration of the internet into the day to day life, everything including design and manufacturing is moving towards being digital. As discussed above the future manufacturing systems will have three unique features. There are high chances that these systems will be more dependent on the internet compared to present day systems as a result of which there can be serious issues related to IP rights. This is where the Blockchain concept discussed in the next section can play an important role in protecting IP rights.

2.2. Blockchain concept

Blockchains are known as decentralized and distributed ledgers compared to the traditionally centralized ledgers that often were used by enterprises to keep the record of their data and information. The history of Blockchain goes back to a white paper released in Oct 2008 by an anonymous person or group of people named Satoshi Nakamoto. In this white paper, Nakamoto described a concept for transferring money from one person to another on a peer-to-peer network without the need for a financial institution. This was an innovation in the financial industry since it was for decades that people were trying to solve a problem known as “double spend” problem. In the white paper, Nakamoto described how sharing information on a peer-to-peer network using a decentralized ledger and the concept of a smart contract could solve the double spend problem without the need for an intermediary or third party such as banks, government or other authorization organizations. In fact, financial transactions could be verified by a group of users on the network known as miners instead of third party financial institutions [21][22]. This was the concept behind Bitcoin as the first digital currency. Later on, the proposed concept by Nakamoto has been applied in the financial market and various cryptocurrencies were released to the market.

Most recently, Blockchain which was initially the technology behind digital money has found its way to different industries and these days, various applications have been identified for it. For example, Blockchain can be widely used in logistics and transportation for tracking shipment containers [23], can be used for identifying counterfeit products and reduction of fraud, can be used for trading energy in smart grids on peer-to-peer networks [24]–[26], can be used for real estate industry for facilitating the purchase and selling process [27], can be used in healthcare industry for tracking patient and data security [28], and can be used in governmental sectors for more secure voting process [29].

Blockchain is in its infancy, but it is recognized by some parties as a General Purpose Technology (GPT) since it has the features of GPTs. Examples of GPTs include the steam engine, electricity and the internet in which any advancement in these technologies would benefit multiple industries and their benefits are extracted over time and are not limited to just one industry [30]. In this study, we would like to discuss how the IP issues arise from the life-sharing features of the internet as one GPT can be solved by employing the capabilities of Blockchain.

The current work is exploratory in nature and serves as an introduction to using Blockchain technology for IP protection. It identifies and discusses three main features of Blockchain technology that can be applied to IP protection for additive manufacturing. To understand the technology and how it will suit the needs of future designers a survey

was conducted. The respondents to the survey were part of two design and manufacturing classes which ensured that they had some exposure to IP issues in design. In addition, they were given exposure to Blockchain technology through class lectures to make sure they had familiarity with the topic. While students are not a representative sample of all users of the future Blockchain platforms, as the young generation they might have already been aware of the IP issues through the entertainment and music industry.

The idea for the IP Blockchain is to develop a private permissioned Blockchain platform using certain types of consensus algorithms. It would not be a public Blockchain platform as is used in the cryptocurrency market. For example, the verification step is not the same as the mining process on digital money platforms such as Bitcoin and Ethereum based on proof-of-work or proof-of-stake. Therefore, the permissioned Blockchain platforms will not have the scalability, energy consumption, and computational challenges of public Blockchain in the financial industry. The main feature of interest in the proposed platform is the concept of public ledger (shared information system) which will be shared among different users of the platform, in contrast to crypto Blockchain platforms in which the main purpose is to limit the use of third-party intermediaries and instead use users of the network as verifiers of the financial transactions (i.e. miners). Such systems can be designed for improving scalability implementing ideas by Vukolic [31].

3. THE PROPOSED BLOCKCHAIN-BASED IP PLATFORM

In this study, we particularly are interested in the capabilities of Blockchain for solving IP challenges in the product design and manufacturing area. Inspired by the application of the Blockchain in the entertainment industry, specifically the music industry, we will discuss the elements of a digital platform built based on Blockchain for keep tracking of the use of product design blueprints.

Blockchain has offered many capabilities, among them we would like to focus on the following three features:

- 1) Reducing the cost of verification and the cost of networking
- 2) Asset tracking to facilitate monitoring the usage of design blueprints
- 3) Providing fair compensation for different users on the network.

The proposed Blockchain platform for protecting patents and design blueprints requires defining three main elements as shown in Figure 3.

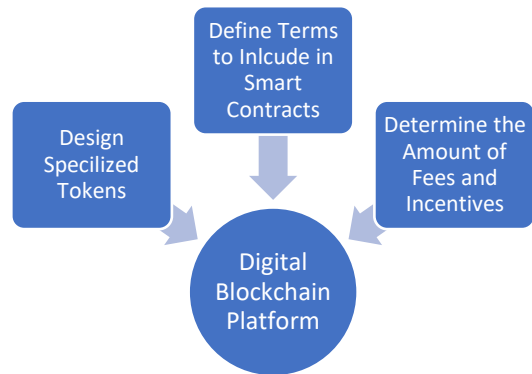


Figure 3: Three main elements for defining a digital Blockchain platform for IP

These three elements are the major questions that should be investigated to develop a Blockchain platform for protecting the right of creators of any contents (e.g. design, patents, invention, art). These elements include: (1) design specialized tokens to reward users behaviors, (2) determine terms to include into the smart contracts, and (3) determine the amount of fee and incentives offered to users on the peer-to-peer network.

3.1. Design specialized tokens to reward users behaviors

The concept of Initial Coin Offering (ICO) or token sale has been widely used in the industry by startups and enterprises for crowdfunding the development of Blockchain platforms. The developers of digital Blockchain platforms use ICO for financing the development cost of Blockchain platforms with preselling the access to future products and services offered on platforms. Although ventures do not give any promise about the future value of the tokens, tokens potentially perform as a medium of exchange (payment mechanism) on Blockchain platforms and the token owners will be able to access the services offered on the platform easier and faster.

If we consider a digital platform for protecting the right of content creators, we need to define a utility token that can perform as local money or medium of exchange on the platform. The question arises as if digital currencies and cryptocurrencies could be used instead of utility tokens. Cryptocurrencies can be used as well, but crypto is very volatile and it may not perform well as a stable medium of exchange, at least as of now (see Figure 4 as one example).

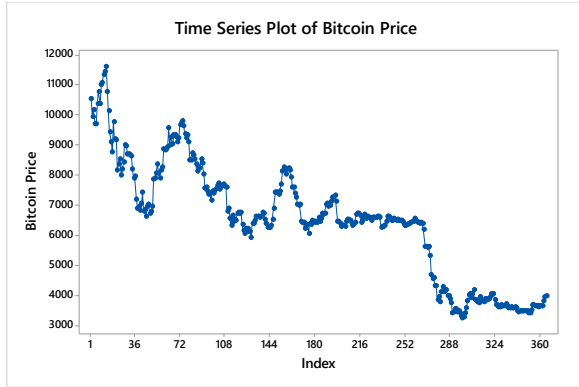


Figure 4: Time series of Bitcoin price as of Feb 2019

3.2. Smart contracts and their capabilities for IP Management

Significant benefits have been discussed in the literature for smart contracts ranging from privacy and no need of an intermediary to self-enforcement and trust. In the previous section, we have described the main reason why designers should employ Blockchain digital platforms for their activities. Smart contracts enable designers to decentralize their services in order to improve privacy and gain economic incentives resulted from their work. Having the capability of copying a design blueprint poses undesirable risks to designers, risks such as data privacy, authenticity, and no control over their properties.

To design Blockchain system for awarding acceptable asset usage behavior, startup, designers and companies should be ready to answer questions such as what behaviors to incentivize, how much to charge certain users, and what to include in smart contracts. Logically, the course of actions taken by users on the platform not only should be legal behavior but also should benefit the economic aspects of the business and designers. However, it is critical to address any misalignment between the business objectives of Blockchain platforms and the final conflicting IP issues. For examples, some of the terms and conditions included in the smart contracts might be time-stamped to encourage certain collaboration and innovation opportunities between different enterprises and groups of users.

Overall, Blockchain platforms offer some helpful capabilities for asset management [32]. These capabilities have been redrafted for the case of asset management as follows:

- 1) Anonymity: platform participants (e.g. buyer and sellers of design blueprints) can be completely anonymous while the asset is transferred from one agent to another given that the buying agent is capable of paying for the asset. The sellers do not need to know the identity of the buyers.

- 2) The asset is transferred based on the ways defined by owners of assets and other parties involved in the transactions of the asset.
- 3) There is no need for an intermediary, so no central entity is needed in such a decentralized system. The smart contract will be hosted on the network rather than a third party organization. In this case, the verification cost is extremely low.
- 4) There is a consensus between different parties on the flow of asset from one party to another and the trust model is understandable.
- 5) Self-enforcement: contracts are self-executed, self-managed, and self-performed.
- 6) The anonymous communication and transaction: all transaction and communications developed on digital platforms are anonymous.
- 7) Reward system: each node on the network is rewarded based on the set of activities carried out by the node.
- 8) Operations cannot interfere with each other.
- 9) Assets, transactions, and information recorded can never be deleted, cannot be changed and are permanently stored on a Blockchain.

Currently, different agreements exist for protecting intellectual properties. However, these agreements are very broad and are not intended to cover the financial benefits of asset owners. Table 1 provides an overview of two types of IPs and their corresponding international agreements.

Table 1: Types of IPs and agreements for protecting them (adapted from [33])

Types of IP	Instruments of Protection	International Agreements
Intellectual Property	Patents Utility models	Paris Convention Patent Cooperation Treaty Budapest Treaty Strasbourg Agreement TRIPS (between members of WTO)
	Industrial Designs	Hague Agreement Locarno Agreement TRIPS
	Trademarks	Madrid Agreement Nice Agreement Vienna Agreement
	Geographical Indications	Lisbon Agreement TRIPS
Trade Secretes	Laws against unfair competitions	TRIPS

The proposed platform in this paper is a digital platform that connects designers through a decentralized verifiable

system, promoting designer-led fair operating activities. The agreements incorporated in such systems are coming from different stakeholders and users of the network/system. Figure 5 shows the proposed concept where a designer establishes a smart contract interconnecting the CAD file, the license to use the file and the payment wallet on a Blockchain platform. Different entities who want to use the CAD file makes a request to use the file and are advised to make a payment to the designer using the wallet. Once payment has been deposited to the wallet, it will trigger the smart contract to activate the license for the file and thus can be used by the licensed entity. Each entity will provide different compensation based on their status. For example, a student can use the design for free. A university will need to pay a minimum fee whereas the design will be most expensive for a multinational company.

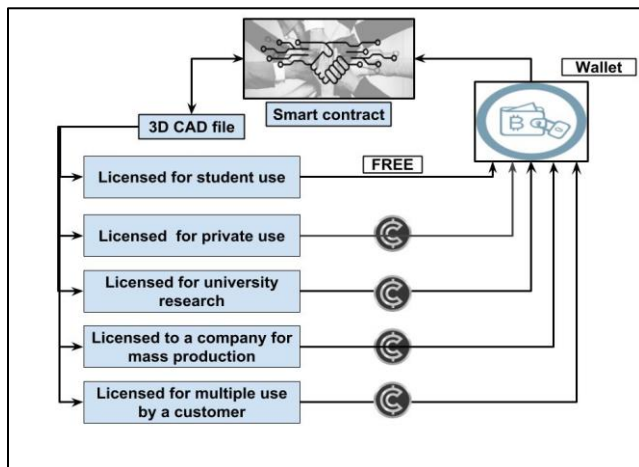


Figure 5: Putting a smart contract around the design asset on the Blockchain for fair compensation system (Note: Some of the icons in the image are adapted from the internet)

4. QUESTIONNAIRE

In this section, we would like to highlight the capabilities of Blockchain for IP asset management and the types of features that should be included in the smart contracts for design blueprints. To identify the features, we have conducted a survey study of students who have been exposed to a training session on Blockchain technology and its implications. The survey was available to more than 150 students in two design and manufacturing courses. The purpose of the survey was to seek opinions of students as future designers as well as future customers of design blueprints about the main motivation behind developing these platforms and the types of features that should be included in Blockchain-based IP platforms, particularly for product design. Total of 80 students have participated in the survey.

Seven main questions have been included in the survey. The purpose of two of the questions was to identify what

capabilities of Blockchain are of interest to designers and why they might like to put a smart contract around their design assets and put them on the Blockchain. Another question was intended to identify which industry (i.e. subtractive manufacturing vs additive manufacturing) is more affected by the threat of fraud and counterfeiting products.

In addition, one question was included to capture respondents' opinions about the impact of putting Blockchain-based IP on the growth and development of the innovation. The purpose was to identify whether limiting the file-sharing that is currently available due to the capability of the internet will limit the growth of innovation in society or not. Moreover, a question was included to capture the opinion of respondents about using similar e-commerce website for selling assets and design blueprints. Finally, two questions were added to measure respondents' level of knowledge about Blockchain and IP issue in the design. We should note that students participating in the survey have already received a training session on the concept of Blockchain.

The questions and the results obtained are as follows. The percentage represents the response submitted for that option.

Q1. Suppose that a company is developing a digital platform based on Blockchain (distributed public ledger) for protecting their Intellectual Property Asset (e.g. patents, industrial design, trademarks, trade secrets). Which of the following features are more important to consider when designing their platform?

- 1) The platform should involve all parties and industry stakeholders. **(15%)**
- 2) The platform should ensure all involved parties are acknowledged and paid according to their efforts and engagement. **(41.3%)**
- 3) The smart contract (agreement between different parties) behind the system should cover all ethical, commercial, and technical standards. **(53.8%)**

- The platform should involve all parties and industry stakeholders.
- The platform should ensure all involved parties are acknowledged and paid according to their efforts and engagement.
- The smart contract (agreement between different parties) behind the system should cover all ethical, commercial, and technical standards.

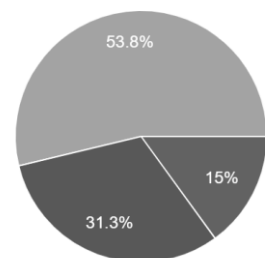


Figure 6: The important features of the IP Blockchain platforms.

Q2. Which of the following industry might be affected more by the threat of counterfeiting?

- 1) Traditional manufacturing/subtractive manufacturing **(22.5%)**
- 2) Additive Manufacturing **(32.5%)**
- 3) No difference. Both industries are affected by the same level **(45%)**

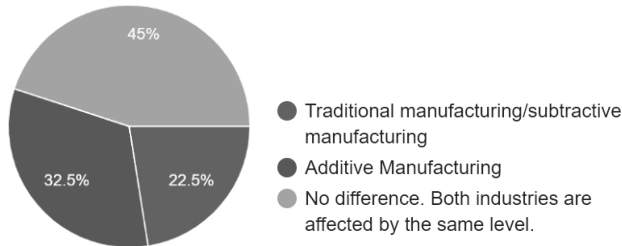


Figure 7: The Industry affected more by IP issues.

Q3. Do you think that digital platforms for selling assets such as design blueprints and patents should be handled similar to e-commerce websites that sell products or would they need different rules and regulations in place?

- 1) I think IP owners should be able to sell their assets similar to other products and services **(35%)**
- 2) The sale of an asset is different from other products and services and they need extra regulations **(47.5%)**
- 3) I have no idea **(17.5%)**

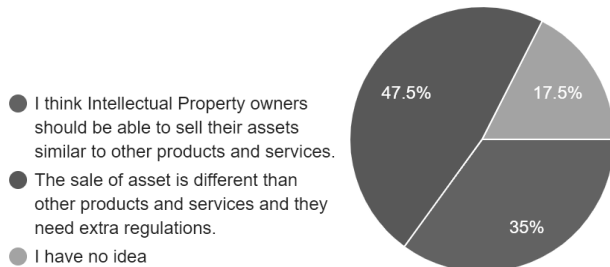


Figure 8: Selling IP assets in comparison with product-based e-commerce websites

Q4. Suppose that you are the owner of a design blueprint what would be your main motivation for defining a smart contract around your asset and putting it on digital Blockchain platform?

- 1) Privacy: I would like to keep my anonymity when my design/patent is transferred or released to the market. **(16.3%)**
- 2) Fair Compensation: I would like to be paid every time my design/asset is used by other users/companies. **(55%)**
- 3) Tracking: I am interested in tracking how many times and who (e.g. consumers, businesses, small

and medium-size companies, etc.) will use my design blueprints. **(28.7%)**

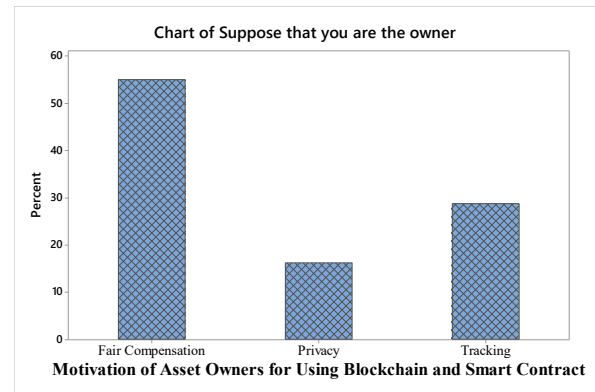


Figure 9: The main motivation of IP owners for using smart contracts and Blockchain platforms

Q5. What do you think would be the impact of IP-based Blockchain on innovation and development growth?

- 1) It would enhance the growth and development of innovation in the manufacturing systems. **(53.8%)**
- 2) It would limit the growth and development of innovation compared to the existing file-sharing technologies. **(13.8%)**
- 3) I have no idea. **(32.5%)**

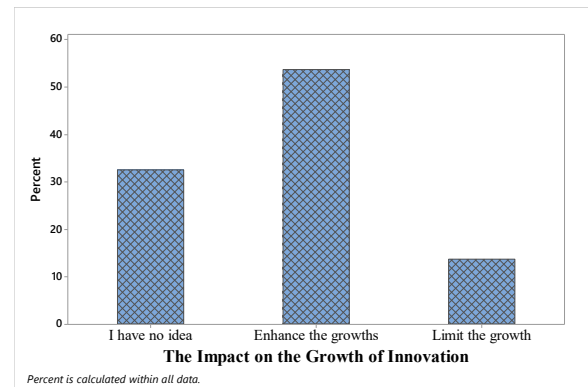


Figure 10: The impact of IP-based Blockchain on the growth and development of innovation

Q6. How familiar are you with Blockchain technology? Please respond on a scale of 1-5, where 1 means not familiar at all and 5 is extremely familiar.

1	2	3	4	5
Not familiar at all				Extremely familiar

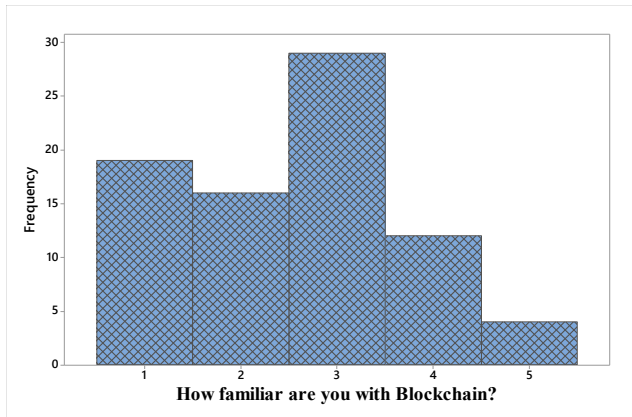


Figure 11: The respondents' familiarity with Blockchain technology.

Q7. How familiar are you with IP issues in the product design area? Please respond on a scale of 1-5, where 1 means not familiar at all and 5 is extremely familiar.

1	2	3	4	5
Not familiar at all				Extremely familiar

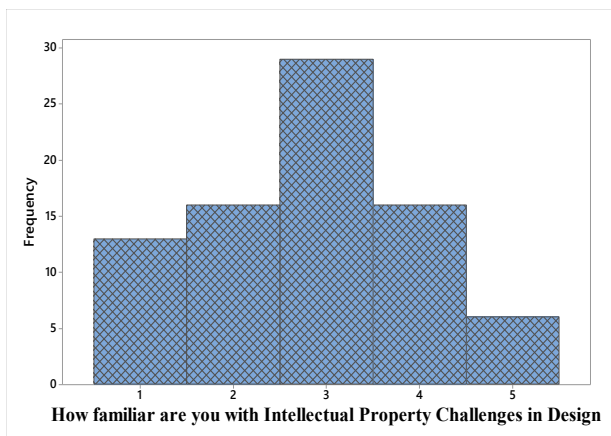


Figure 12: Respondents' awareness of the IP issues in the product design area.

The result of the survey shows that the “smart contract” feature is the main reason that designers might be interested in using Blockchain platforms. They believe both additive manufacturing and traditional manufacturing are prone to be affected by the threat of counterfeiting products and blueprints. Most of the respondents believe that the sale of an asset is different from other products and services and they need extra regulations. “Fair compensation” is the main motivation of future designers for putting a smart contract around their asset and implement it on Blockchain platforms. More than 50% of respondents believe that the use of Blockchain technology for IP protection would

increase the growth and development of innovation rather than limiting it.

5. CONCLUSION AND FUTURE WORK

The study introduces the concept of Blockchain and discusses the capabilities of this technology for protecting Intellectual Property in design and manufacturing area. It proposes a digital platform for solving the file-sharing capabilities offered by the interest. The study further discusses three main steps for designing a digital platform based on Blockchain technology: (1) design specialized utility tokens, (2) define terms to include in smart contracts, and (3) determine the amount of fee and incentives for each stakeholder accessing the platform.

A questionnaire has been designed to capture the opinion of engineering design and manufacturing students about the capabilities of Blockchain that might be of interest to the design community and how the new digital platforms may affect the growth and development of innovation in the society.

The paper can be extended in several ways. The survey can be extended to existing businesses or companies that possibly face IP issues. In addition, a more representative sample of all future users of the platforms should be included in the survey ranging from asset owners to platform developers, manufacturers, and third-party asset users. A prototype of the digital platform can be developed and its capabilities can be tested in practice, especially in existing AM cloud-based businesses. The terms and conditions that should be included in these digital platforms should be extracted based on extensive research work. Computationally efficient mathematical models should be developed to support the consensus algorithms and smart contracts. The verification mechanisms are needed to verify transactions happening on the Blockchain and certified users, inspectors, and vendors should collaborate to reduce the cost of verification and networking.

Acknowledgements

This material is based upon work supported by the National Science Foundation–USA under grant # CMMI-1727190. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES:

- [1] B. Depoorter, “Intellectual Property Infringements & 3D Printing: Decentralized Piracy,” *Hastings Law J.*, vol. 65, no. 6, pp. 1483–1503, 2014.
- [2] J. Kietzmann, L. Pitt, and P. Berthon, “Disruptions, decisions, and destinations: Enter the age of 3-D

- printing and additive manufacturing,” *Bus. Horiz.*, vol. 58, no. 2, pp. 209–215, 2015.
- [3] M. Yampolskiy, T. R. Andel, J. T. McDonald, W. B. Glisson, and A. Yasinsac, “Intellectual Property Protection in Additive Layer Manufacturing: Requirements for Secure Outsourcing,” in *4th Program Protection and Reverse Engineering Workshop, Association for Computing Machinery (ACM)*, 2014, pp. 1–9.
- [4] T. Kurfess and W. J. Cass, “Rethinking Additive Manufacturing and Intellectual Property Protection,” *J. Res. Manag.*, vol. 57, no. 5, pp. 35–42, 2014.
- [5] D. Mendis and D. Secchi, “A Legal and Empirical Study of 3D Printing Online Platforms and an Analysis of User Behaviour,” 2015.
- [6] Y. Lu and X. Xu, “Protecting intellectual property in a cloud manufacturing environment: Requirements and strategies,” in *IFIP Advances in Information and Communication Technology*, 2015, vol. 460, pp. 404–411.
- [7] D. T. Matt, E. Rauch, and P. Dallasega, “Trends towards Distributed Manufacturing Systems and modern forms for their design,” in *9th CIRP Conference on Intelligent Computation in Manufacturing Engineering*, 2015, pp. 185–190.
- [8] D. Mourtzis, M. Doukas, and F. Psarommatis, “Manufacturing Technology Design and operation of manufacturing networks for mass customisation,” *CIRP Ann. - Manuf. Technol.*, vol. 62, no. 1, pp. 467–470, 2013.
- [9] M. Attaran, “The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing,” *Bus. Horiz.*, vol. 60, no. 5, pp. 677–688, 2017.
- [10] G. Seliger, *Sustainable Manufacturing: Shaping Global Value Creation*. Springer, 2012.
- [11] T. Bernhardt and R. Pollak, “Economic and Social Upgrading Dynamics in Global Manufacturing Value Chains: A Comparative Analysis,” 2015.
- [12] Y. Kristianto, A. Gunasekaran, and P. Helo, “Building the ‘Triple R’ in global manufacturing,” *Int. J. Prod. Econ.*, vol. 183, no. C, pp. 607–619, 2017.
- [13] S. H. Huang, P. Liu, A. Mokasdar, and L. Hou, “Additive manufacturing and its societal impact: A literature review,” *Int. J. Adv. Manuf. Technol.*, vol. 67, no. 5–8, pp. 1191–1203, 2013.
- [14] J. Holmström, J. Partanen, J. Tuomi, and M. Walter, “Rapid manufacturing in the spare parts supply chain: Alternative approaches to capacity deployment,” *J. Manuf. Technol. Manag.*, vol. 21, no. 6, pp. 687–697, 2010.
- [15] F. Pérès and D. Noyes, “Envisioning e-logistics developments: Making spare parts in situ and on demand: State of the art and guidelines for future developments,” *Comput. Ind.*, vol. 57, no. 6, pp. 490–503, 2006.
- [16] P. Reeves, “Rapid manufacturing for the realisation of ‘user described’ entertainment and recreational content,” in *International Conference on Additive Technologies, ICAT*, 2008.
- [17] G. Chryssolouris, D. Mavrikios, N. Papakostas, D. Mourtzis, G. Michalos, and K. Georgoulas, “Digital manufacturing: History, perspectives, and outlook,” *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.*, vol. 223, no. 5, pp. 451–462, 2009.
- [18] I. Gibson, D. Rosen, and B. Stucker, *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*, 2nd ed. Springer, 2015.
- [19] A. O. Andrisano, F. Leali, M. Pellicciari, F. Pini, and A. Vergnano, “Hybrid Reconfigurable System design and optimization through virtual prototyping and digital manufacturing tools,” *Int. J. Interact. Des. Manuf.*, vol. 6, no. 1, pp. 17–27, 2012.
- [20] P. K. Paritala, S. Manchikatla, and P. K. Yarlagadda, “Digital Manufacturing- Applications Past, Current, and Future Trends,” in *Procedia Engineering*, 2017, pp. 982–991.
- [21] M. Iansiti and K. R. Lakhani, “The Truth About Blockchain,” *Harvard Business Review*, no. February, 2017.
- [22] C. Catalini and J. S. Gans, “Some simple economics of the blockchain,” National Bureau of Economic Research, 2016.
- [23] K. Sadouskaya, “Adoption of Blockchain Technology in Supply Chain and Logistics,” 2017.
- [24] Z. Li, J. Kang, R. Yu, D. Ye, Q. Deng, and Y. Zhang, “Consortium blockchain for secure energy trading in industrial internet of things,” *IEEE Trans. Ind. Informatics*, vol. 14, no. 8, pp. 3690–3700, 2018.
- [25] N. Z. Aitzhan and D. Svetinovic, “Security and privacy in decentralized energy trading through multi-signatures, blockchain and anonymous messaging streams,” *IEEE Trans. Dependable Secur. Comput.*, vol. 15, no. 5, pp. 840–852, 2018.
- [26] M. Andoni *et al.*, “Blockchain technology in the

energy sector: A systematic review of challenges and opportunities,” *Renew. Sustain. Energy Rev.*, vol. 100, pp. 143–174, 2019.

- [27] A. Spielman, “Blockchain: digitally rebuilding the real estate industry.” Massachusetts Institute of Technology, 2016.
- [28] M. Mettler, “Blockchain technology in healthcare: The revolution starts here,” in *e-Health Networking, Applications and Services (Healthcom), 2016 IEEE 18th International Conference on*, 2016, pp. 1–3.
- [29] R. Osgood, “The future of democracy: Blockchain voting,” *COMP116 Inf. Secur.*, 2016.
- [30] E. Kane, “Is Blockchain a General Purpose Technology?” 2017.
- [31] M. Vukolić, “The Quest for Scalable Blockchain Fabric : Proof-of-Work vs. BFT Replication,” in *International Workshop on Open Problems in Network Security*, 2015.
- [32] V. Morabito, “Business innovation through blockchain,” *Cham Springer Int. Publ.*, 2017.
- [33] K. E. Maskus, *Intellectual property rights in the global economy*. Peterson Institute, 2000.