A decentralized paper dissemination system employing blockchain technology, peer review and expert badges

***Abstract*—Peer review represents the status-quo when it comes to evaluating research articles that are submitted to conferences and journals. The significance of a computer science article is given by the prestige of the publication and is correlated with the inclusion in the ISI Web of Science index.**

This paper discusses the issues of the current paper publication paradigm and proposes a decentralized approach to the paper dissemination and the peer review processes. On the one hand, decentralization and transparency are obtained by employing smart contracts, through blockchain technology. On the other hand, an optimization of the paper rating system is obtained by employing a system of expert badges, based on NFTs, which ensure that the peer review process is just and that only specialists in the fields associated to the contributed paper offer proficient feedback. Other proposed facets include the remuneration of reviewers, a method of allowing the proposed system to expand based on the community's input, and a solution for allowing the organization of conferences.

***Index Terms*—web technologies, application software, educational applications**

I. Introduction

Access to high-quality research is a critical matter when it comes to developing new methods and techniques for problem solving, or to proposing innovations in various fields of study. Researchers showcase their ideas by writing articles and presenting them at conferences or publishing them in journals. Regardless of the publication method, the article validation involves a peer review process, which implies that members of academia and experts in their fields evaluate the article and offer notes on how to improve its quality.

The peer review process [1], which is currently accepted as the status quo, is not without flaws. The associated paper submission flow that ends with an article being published consists of editors who aggregate the feedback from reviewers and then decide if the paper is relevant enough to be published. An important aspect that can taint this flow is the integrity of authorship and, specifically, unethical peer review [2]. This can lead to paper retractions, a decrease in trust of the involved journal or conference, and of the overall peer review process.

As a vital element of scholarly research quality assurance, peer review plays a significant role in shaping the hierarchical structure of academia and influencing research careers, by conferring academic prestige and legitimacy. Despite its crucial importance, the understanding of peer review's efficacy remains limited, and research in this area is often inconclusive or conflicting [3]. This has resulted in polarized debates, as some consider peer review a "golden standard" [4], while others view it as a defective system [5]. In order to ensure fairness, it is essential to closely monitor and continually innovate the process of peer review, especially as the scholarly communication landscape evolves to include Open Scholarship, interdisciplinary collaboration, and diverse stakeholders [6].

Currently, there is no adequate method of checking if a reviewer read the whole article or just skimmed through the introduction and offered a superficial review. Such superficial reviews offer no assistance to the author on how to improve the paper and no insight to the editor, who has to decide if the paper gets published.

Another issue is the reviewer's level of knowledge regarding the paper's topic. Usually, manuscript management systems allow reviewers to input their degree of confidence regarding their expertise on the topic. This, however, is no real indicator respective to their level. A finer approach is impartially validating the reviewer's knowledge and ensuring that the paper is handled by experts.

The purpose of this paper is to provide the framework for constructing a solution which uses peer review and facilitates access to the published papers. This is achieved by integrating new technologies, such as blockchain, into the traditional process of article reviewing, which currently creates concerns regarding integrity and accuracy. Most platforms used for peer review are centralized, which implies the existence of a third party control, instead of a community driven alternative.

II. Background

A. Blockchain

Blockchain is an immutable ledger that is continuously updated and shared among a network of peers. Maintaining a secure and decentralized record of transactions makes this technology an excellent tool for delivering and tracking information, which is why many systems and applications utilize it [7]. Blockchain is free from censorship, it does not control any single party, instead, it relies on the trustworthy network of nodes and on consensus protocols for validation. In addition to this, blockchain is also immutable and transparent, since data cannot be tampered with, due to the fact that

Funding: This research was supported by the project "Collaborative environment for developing OpenStack-based cloud architectures with applications in RTI" SMIS 124998 from The European Regional Development Fund through the Competitiveness Operational Program 2014–2020, priority axis 1: Research, technological development and innovation (RTI)—the POC/398/1/1 program.

any change will reflect in all the other nodes. In order to maliciously alter the state of a blockchain, more than 50% of all the computing power from the network would be required. Removing all third-party interventions creates an efficient system and reduces the cost for the business.

In the context of this paper, the security employed by blockchain means that the data record can no longer be manipulated by other entities looking to profit from the work of others. An unaltered history of all paper submissions and all provided reviews is permanently available. Furthermore, third party removal allows self-management inside the scientific community, accelerates the peer review process and reduces costs.

B. Ethereum Blockchain and Smart Contracts

While the primary objective of the Bitcoin blockchain was to enable decentralized digital currency and facilitate the exchange and storage of value, the Ethereum blockchain has a more diverse range of applications. It is a programmable platform that establishes a peer-to-peer network, and its capabilities extend beyond financial transactions [8]. Ethereum blockchain has a wide range of applications in various fields, including finance, web browsing, gaming, and more. The Ethereum network securely verifies and executes application code through its Virtual Machine, called smart contracts.

A smart contract is a piece of code deployed within the Ethereum network, which cannot be modified after its deployment. It operates independently, without interference from its creators or other intermediaries, and is automatically enforced. This unique feature provides a new level of security and trust in digital transactions, as all parties involved can rely on the code executing exactly as written, with no possibility of manipulation. The Ethereum blockchain is considered to be a revolutionary technology [9], enabling a range of decentralized applications with numerous possibilities for innovation and transformation.

C. Non-fungible tokens

Non-fungible tokens, also referred to as NFTs, are cryptographic assets, that rely on blockchain technology and are designed to prohibit interchangeability with other assets. Originally, virtual objects were thought to be indistinguishable from one another, but digitally distributed ledger systems brought innovations that created grounds for non-fungible items [10].

Through the use of NFTs, one can prove the ownership of a digital asset, in the form of an image, song, video, character from a game or ticket to an event. Although still in its infancy, this technology has been adopted in different sectors, such as: digital collectibles, characters in games [11], securing ownership of domain names [12], music [13], or even sneakers in the fashion industry [14]. Furthermore, features like traceability, deep liquidity and convenient interoperability suggest that this technology is a ”promising intellectual property (IP) - protection solution” [15].

D. Double-blind reviews

A double-blind review process implies that the identity of the reviewer, as well as the identity of the author are concealed throughout the entire peer review process. In a centralized approach, only the editor knows the identity of both parties, but in a decentralized approach, no other third party is involved, so the anonymity is completely guaranteed.

One of the advantages of double-blind reviews is that they eliminate bias towards articles written by consecrated authors or submitted by members of a top university [16]. Furthermore, double-blind reviews have proved to significantly increase the number of articles published by female authors and by doing so, they also effectively overcome gender bias [17].

The proposed system uses double-blind reviews as means to preserve integrity. Neither the reviewer, nor the author know any information about the other entity, during the peer review process. However, the system creates a culture of accountability, by sending the information regarding identity to a smart contract, at the end of the review period.

E. InterPlanetary File System (IPFS)

InterPlanetary File System (IPFS) is a distributed and decentralized file system, based on the peer-to-peer network model. The goal of IPFS is to provide a faster, more efficient, and more secure way to store and access content, such as documents, images, and videos, without relying on a centralized server [18]. IPFS uses content-based addressing, which means that each file is given a unique hash, which can be used to retrieve the file from any node on the network that has a copy of it. This means that the content is not dependent on a specific server or location, and that it can be accessed faster and with less bandwidth than traditional web hosting [19].

In the proposed Paper Dissemination System, IPFS is used to store the metadata for NFTs. NFTs rely on metadata, which includes information about the digital asset, such as the name, description, and unique attributes, to verify ownership and authenticity. The unique hash assigned to each piece of metadata acts as a digital signature, therefore, by storing the metadata on IPFS, it is virtually impossible for anyone to falsify ownership or modify the attributes of an NFT.

III. Related Work

Editorial peer reviewing has been around since the 20th century and the institutionalization of the process served the purpose of meeting demands regarding objectivity in an increasingly specialized world [20]. Nevertheless, the means of evaluation are no longer fit for today’s increase in the number of paper submissions, which has led to rushed and perhaps superficial reviews [21].

Internet based peer review systems constitute over 80% of publisher employed systems, according to ALPSP [22]. The Open Access and Open Science movements have come very far regarding cutting costs for information access. These movements have managed to set aside previous cultural borders and create the means for global scientific exchange and equal chances.

However, one of the most emphasized adversities of the system is the lack of quality control. It appears that this unreliability comes from the fact that approximately six reviewers would be needed for quality assurance, whereas, in practice, editors typically use two or three [23]. One study [24] discovered that the odds of two reviewers agreeing when it comes to a particular paper were only slightly better than chance.

There are several well-known peer review systems for conferences and journals like PaperCept [25], EasyChair [26] or MDPI [27]. These solutions use the same peer review process, containing the deficiencies which were previously discussed in this paper. MDPI has the advantage of also publishing papers in an open-access manner, i.e., once published, anyone can access those articles without paying any fee. This is due to the fact that the author pays a fairly large amount of money to get the paper published.

Alternatives that challenge traditional publication processes have been around for some time. Preprints are full draft research papers that are shared publicly without peer review ing, which enables writers to gain more visibility [28]. Such initiatives tackle the concern regarding reviewer unfairness by removing the peer review process completely from the publishing scheme. However, some argue against this [29], in the sense that even slightly biased reviews can sometimes prove more beneficial than the complete absence of peer reviews.

The BMIF Journal [30] suggests a peer review process that is double-blinded, for both reviewers and authors, which should prevent all entities from forming bias.

The Hyperjournal project has a distinctive approach, because it stores the accepted, as well as the rejected articles in its repository. This is a method of acknowledging that the notion of quality is strictly correlated with other extrinsic factors [31].

All of the above mentioned system share one identical characteristic: centralization. Centralization means bureaucratic leadership, which often implies that some entities have disproportionate power. In this context, third parties have more control than the scientific community and editors have more authority that it is necessary. The data record may also be manipulated, e.g., by malicious conference organizers or editors who plan to plagiarize from submitted work [32]. Decentralized systems eliminate such issues by employing traceability. Furthermore, if there is no more need to pay the editor, there is more money for the reviewers, in order to ensure the quality of their work.

The current motivations for people to participate in peer reviewing are prestige and the desire to determine quality in a research area [33]. Nevertheless, a financial motivation could benefit everyone from the scheme.

One decentralized approach is a currency system for academic peer review [34]. In the proposed exchange system, the users are paid with a cryptocurrency called r-coin, which can be further used for the cost of publishing in a journal. Another decentralized approach, which involves a tokenized peer review system [35] as well, suggests penalties for members that do not uphold the agreed standard.

Nevertheless, creating a currency for peer review systems cannot provide the means to solve the problem of having too few people that offer reviews. A cryptocurrency that can be used solely to publish in a journal will probably not attract many new people into the ecosystem. The infrastructure for exchanging cryptocurrency is still in its infancy. Therefore, exchanging r-coin for another more widely used coin could actually mean losing money, due to fees. Until the infrastructure evolves further, coins with a broader use remain a preferred choice. The proposed Paper Dissemination System offers payment in a more popular coin, Ether, that people can use for other transactions as well, without having them limited to a token that only has value inside the academic peer reviewing system.

Name of the system	Decentralized	User Remuneration	Double-blind reviews
Preprints	✗	✗	✗
BMIF Journal	✗	✗	✓
Hyperjournal	✗	✗	✓
R-coin	✓	✓	✗
PDS	✓	✓	✓

Fig. 1. Comparison of the proposed system (PDS) with other similar solutions

IV. Proposed solution

A. Overview

The proposed Paper Dissemination System focuses around three main concerns: how can people be persuaded to offer scientific reviews, what should be an equitable rewarding system for those with a valuable contribution and how can authors be ensured that reviewers are qualified to assess their papers.

As a solution to the first problem, users of the presented system receive payment upon reviewing an article. In a decentralized approach, the payment amounts to a sum of a cryptocurrency added to each individual wallet. However, solely paying people to offer a review would not assure quality, therefore, additional precautions need to be taken.

Rather than instantly paying reviewers, without taking into account whether the information provided was valuable, a better approach would be to wait until the allowed time for reviews has expired. Afterwards, a decision must be taken regarding how much a user should be rewarded, based on how close the grade he offered the paper was to the average of grades.

However, not even that is sufficient to ensure a fair peer review process, since inexperienced people could potentially influence the overall score of the article. In order to prevent that, a reviewer is asked to take one or more skill tests, prior

to grading a paper. When adding an article into the network, the author chooses which are the main subjects addressed and selects them from a list of tags. For each of these, a minimum required level is set, to state what qualifications are mandatory for a reviewer when assessing the paper.

Following every successfully passed skill test, the user receives a badge attesting the level (beginner, intermediate or expert), in the form of a non-fungible token (NFT) [15]. A reviewer is able to grade a paper only if the minimum requirement level is met, for each tag set by the author.

The novelty of the proposed system relies on employing technologies like blockchain, smart contracts and non-fungible tokens, in order to solve some of the existing problems regarding the peer review process.

B. System architecture overview

From a technical point of view, the Paper Dissemination System's architecture (Fig. 2) consists of a Front-end Server, a Back-end Server, which interfaces with a FileSystem and a database, the Ethereum blockchain solution employing Smart contracts and the Metamask provider.

The Front-end Server is a web interface that allows the user to view, add and review papers, and to obtain badges by passing skill tests. There are two situations in which the users have to use their Metamask wallet via the Metamask browser plugin. The first one is when submitting a paper, because the author has to pay upfront, and the second one is after the user submits the solution to a test and receives the corresponding badge, in the form of an NTF.

The business logic is processed by the services from the Back-end server, which handle user, paper and badge management, skill testing and reviewing papers, and by the logic in the Smart contracts, which take note of the changes in a decentralized public ledger (i.e., the blockchain). IPFS is used to store the metadata for the NFTs, while a database is used to store user, paper, badge and skill information, and a file storage solution is employed for keeping the papers until the reviewing process is over.

C. Obtaining a badge

Skill badges constitute a fundamental part of the presented system. They ought to assure the authors that whoever reviews their paper is qualified to do so. The system provides a wide variety of test topics, for which, upon completion, a user can either be awarded a badge, or not, depending on the score.

The steps that need to be taken in order for a user to be awarded a badge:

1) Obtain the test for the desired topic from the server.
2) Complete the test.
3) Submit the responses to the server, which:
    a) computes the score,
    b) determines the user's level on that topic,
    c) stores the information in the database,
    d) returns the token URI corresponding to the badge type and level.
4) Obtain the badge automatically by means of a smart contract:
    a) sign the transaction containing the token URI and the recipient's address,
    b) call a method from the smart contract that mints the NFT.

Every badge also comes linked with a skill-level: beginner, intermediate or expert. All badges act as NFTs, so that participants are granted complete ownership.

D. Submitting an article for review

All the research papers submitted into the system must adhere to the same template (e.g. IEEE trans template). A standard, flat fee, is applicable for a six page document, represented in a two-column format. For every two pages, a surcharge is added to the sum of money an author must pay, in order for the reviewers to be paid proportionally to the amount of time the peer review process requires.

The necessary steps for an article upload:

1) Article is uploaded into the browser
2) Article is submitted along with the associated topics and their level
3) Server saves the document in the file system
4) Paper related information is saved in the database: paper name, authors, short description, associated topics, file path, timestamp and a payment status
5) Payment is executed through a smart contract and the user has to:
    a) sign the transaction
    b) pay the required amount, plus gas
6) Smart contract emits an event, after the payment is processed
7) On a separate thread, the server listens for the event and once it is emitted, changes the payment status from the database

The payment is required upfront, with the intention to assure reviewers that their work will be remunerated. Due to the money being stored and redistributed by means of a smart contract, both authors and reviewers are assured that the process is fair and tamper-proof.

E. Reviewing an article

The peer review process is divided into two separate phases, as shown in Fig. 3. The first phase, entitled private review, is meant to help the author improve the quality of the paper, while the second phase represents the final evaluation.

The flow which is common to both stages of the peer review is described below:

1) Check to determine whether the user owns the required skill badges with the necessary level
2) Complete the review
3) Submit the response, which is:
    a) processed by the server
    b) saved into the database

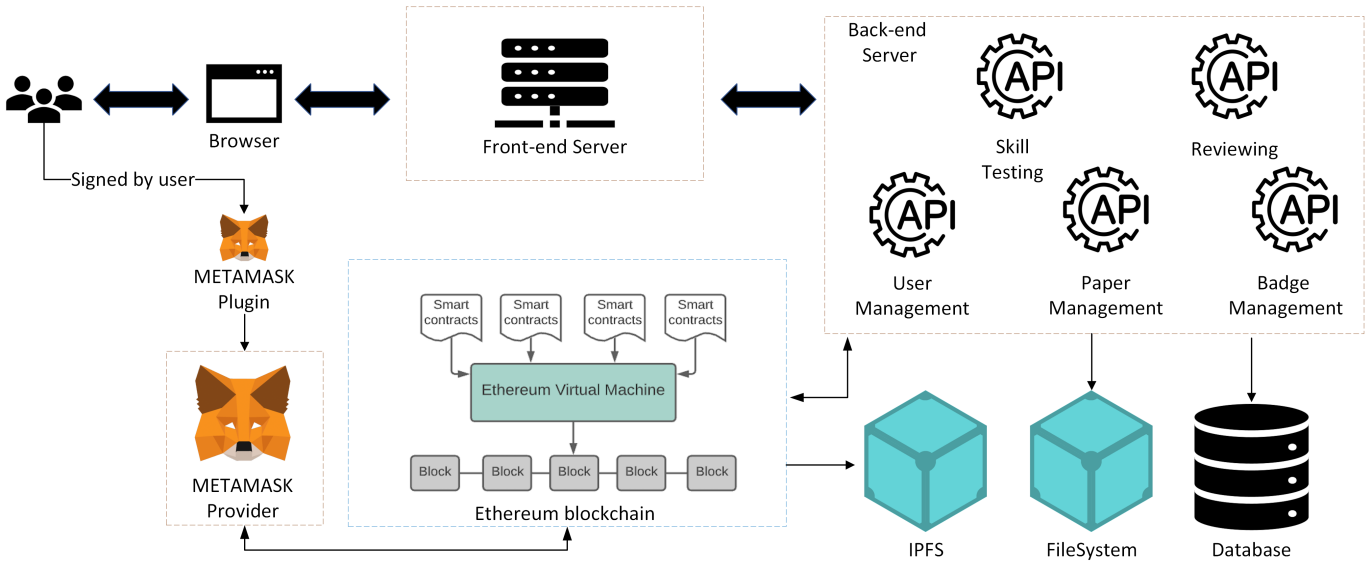

Fig. 2. Paper Dissemination System architecture

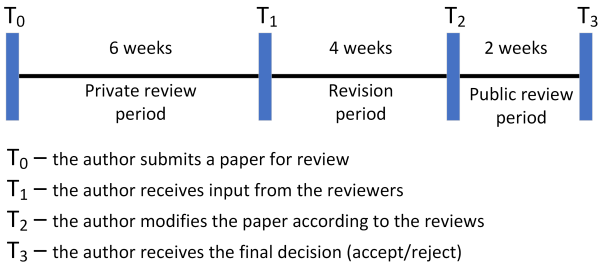

Fig. 3. The phases of the peer review process

A final decision regarding the paper is made at the end of the public review period. The server computes an average of all grades offered by reviewers, which is considered the final article grade. Provided that the overall score passes the quality threshold, the paper is hashed and then sent to the same smart contract that received the author's payment, along with all grades offered by the users and the amount of money each user should receive.

F. Remunerating users

During the two distinct peer review stages proposed, the same reviewers are involved, and they only receive payment upon completing the second one, to ensure that their work is thoroughly finalized.

Users receive payment as follows:

1) Cron job checks if the public reviewing period for each paper is over
2) If there are not enough reviews, then the reviewing period is extended
3) Otherwise, the overall paper's score is computed
4) Data is sent to the same smart contract that received the author's payment
5) Funds are transferred from the smart contract into wallets

Each reviewer gets a part of the sum of money payed by the author, depending on how far off the given score was from the mean.

Let n be the number of reviewers for a specific article and x_k the score given by reviewer k, then the revenue (R_k) for reviewer k is computed as shown in (1). The value $\bar{x}$ represents the arithmetic mean of the reviewer scores for that article, and S_n represents the sum of the inverse deviations from the mean (2). A value of one is added to the fraction denominator because, otherwise, if the reviewer's score is exactly the same as the mean, the fraction will evaluate to infinity.

$$R_k = \frac{1}{|\bar{x} - x_k| + 1} \cdot \frac{1}{S_n} \quad \text{, where} \tag{1}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \text{and} \quad S_n = \sum_{i=1}^{n} \frac{1}{|\bar{x} - x_i| + 1} \tag{2}$$

V. Efficiency Discussion

A. Community input

The Paper Dissemination System aims to be a community-driven alternative to the current peer review process. To serve this purpose, apart from the predefined tests, which will be available in the platform, the community can vote for new test topics, questions and correct answers and can upload metadata which will be then be added to the InterPlanetary File System (IPFS).

Any member can submit a proposal for a new test topic, along with a set of questions and correct answers. Also, the user has to upload an image for the corresponding NFT and a file in JSON format, containing the metadata for the NFT. When this information is uploaded, a period of time

is allocated for community discussion, feedback and voting. Provided that the majority agrees, the test is considered valid. At the end of the time window, a cron job uploads the NFT corresponding data to IPFS and stores the content identifiers and the questions, with their answers in the database.

B. Conference organization

Conferences offer a glimpse into the latest trends of the industry. They constitute a fundamental part of the scientific community and pave the way for progress. The reasons for attending a conference expand beyond the ones for writing a paper. A conference represents an opportunity for like-minded people to exchange information, even beyond their field of interest and to publicly showcase their ideas, which can lead to new ideas and opportunities.

The Paper Dissemination System provides the tools for conference organization. Any member can publicly create a conference topic, under which papers can be posted. The creator can specify which tags are acceptable for articles (the domains of interest of the conference). The peer review process takes place in the exact same manner in which it has been previously described, with the difference that a paper passing the quality threshold concludes in not just the persistence of that paper on the Ethereum blockchain, but also the invitation of the authors to attend the conference.

C. The purpose of web services in the proposed system

In the context of the proposed system, the Ethereum blockchain is employed when users are awarded a badge, when the author uploads an article and at the end of the public review stage, when users are remunerated. The remaining business logic is provided by the web services.

When a function inside a smart contract is called, the user initiating the transaction has to pay a sum of money, called gas, in order for the network of peers to validate the transaction. The amount of gas required for each transaction depends on how complex the exchange is. A transaction which calls a function inside a smart contract that executes a complex processing is more expensive than a simple money transfer, for instance. Therefore, in order to mitigate some of the financial responsibility from the end user, the proposed system uses web services for the business logic which involves heavy processing and then sends the results to the smart contracts.

D. Cloud deployment

As it stands, the paper and review information is stored on the decentralized Ethereum blockchain. A deployment on a Cloud solution can significantly improve the scalability of both the front-end and back-end servers. In order to further adhere to the decentralized and transparency concepts, the proposed solution is designed to be easily deployed to the open-source OpenStack solution. Each service component of the back-end server can be deployed to different instances with the Nova instance controller, and the information can be saved with block and object storage using the Cinder and Swift services.

If there is need to have the proposed system deployed in an isolated environment, a potential improvement can be made by employing Openstack's Heat service, which allows orchestration. This way, with a carefully crafted template, the proposed solution can be easily deployed to any Openstack infrastructure.

VI. Conclusion

The proposed Paper Dissemination System represents a decentralized solution, meant to persuade more experts to connect with the scientific community, by offering peer reviews, and receiving payment for their contribution. The system is also devoted to building a trust-worthy network of peer reviewers, all of which have been rigorously assessed, prior to grading a paper.

By employing smart contracts, non-fungible tokens and blockchain technology, the system establishes autonomy, traceability and becomes tamper-proof. Double-blind reviews eliminate bias, while the involvement of the previously mentioned technologies creates a culture of accountability. All these features build the infrastructure for a community-driven alternative to the current peer review process and by doing so, solve the existing issues regarding unreliability and challenge the traditional involvement of third parties.

One potential direction for future development could be to move towards complete decentralization of the system, with the business logic provided solely through smart contracts, without the need for web services. This would provide even more flexibility and autonomy to the system. In such a manner, user privacy would be intrinsically guaranteed and no additional personal information would be required when creating an account. However, in such a decentralized context, ensuring accountability would be a challenge.

The current approach could also benefit from integrating a reputation score for users, based on the feedback from other members, the number of reviewed articles and how valuable the review was. A higher score is correlated with having an opinion that is more valuable to the community. Therefore, when decisions inside the system are made, such as adding a new test topic, a vote from such a user weights more.

Taking into account the fact that Paper Dissemination System makes use of a variety of technologies which are still in their infancy, it remains up for debate whether these will prove capable of creating the complete infrastructure that the peer review process requires.

All things considered, the opportunities that arise from integrating new technologies into consecrated areas, out-weight any potential risks, by far. In such a manner, the way towards advancement is steadily paved.

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