DJournal: A blockchain based scientific paper reviewing system with self-adaptive reviewer selection sub-system

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Abstract

The paper reviewing process evaluates potentiality, quality, novelty, and reliability of an article prior to any scholarly publication. However, a number of recent publications are pointing towards the occurrence of the biasness and mistreatments during the progression of the reviewing process. Therefore, the scientific community is involved to standardize the reviewing protocols by introducing blind and electronic submission, selecting eligible reviewers, and supporting an appropriate checklist to the reviewers, and etc. The amplification of reviewing with decentralization and automation can solve the mentioned problems by limiting the possibility of human interaction. This article proposes and implements a decentralized and anonymous paper reviewing system (DJournal) using blockchain technology. DJournal eliminates all the trust issues related to the reviewing process but improves reliability, transparency, and streamlining capabilities with up-gradation of the machine learning-based reviewer selection approach.

KEY WORDS Autonomous Paper Reviewing System, Blockchain, IPFS, Machine-Learning, Smart Contract

INTRODUCTION

Scientific paper reviewing is a process of critically appraise, examine and evaluate research quality and secure essential features, substantive appearance, related evidence current findings on theoretical and methodological innovations and their proofs by the domain experts (Mulligan, Hall & Raphael, 2012, p. 132-161). Therefore, reviewing can be considered as the backbone and the final metric of analysis for publishing a research work, for approving a grant application, or for offering a reward, and etc. Considering the above involvement of reviewing in scientific communities, it is necessary to keep reviewing more transparent, trustier and freer from human relate prejudices including author's reputation, gender, and institution rather than their submission quality. Reviewing should provide a valuable judgment and constructive feedback, and thus helps to contribute to the scientific discoveries (Kelly, Sadeghieh & Adeli, 2014, p. 227–243). In this regard, publishers or relevant organizations follow devise strategies including blind reviewing, double-blind reviewing, and etc. to improve their reviewing and ensure fewer biases but more trustful and more transparent system. However, still many peer-reviewing frauds are detected and removed from various journals for biased reviewing (Stoye, 2019) (Mahoney, 1977) including Sage publications removed 60 research papers for exploiting peer reviews (Fanelli, 2009). In the traditional reviewing process, the biasness can occur at the very beginning (assignment phase) of a systematic reviewing process. Here, a submitted paper can be influenced by the editor and can contribute biasness. Reviewers can also be biased or offer biased reviews. The whole reviewing process is questionable if anyone from the editor or reviewers forgets his/her ethical norms and drowns into dishonesty. Thus, a new peer-reviewing system is needed to solve the drawbacks of existing traditional reviewing system and assigns reviewers a submitted research paper automatically without any human interaction (Clarke, 2013). In this paper, we present a reviewing system without any explicit influencing factors, biasness, or un-trust issues, but with more trustful and more transparent. The proposed system improves the reviewing process and resolves all un-trustful issues with the following contributions:

1. The article implements a blockchain-based decentralized and automated reviewing system named "DJournal", with the help of a smart-contract and IPFS.
2. DJournal integrates a machine learning-based self-adaptive process for choosing appropriate reviewers for a submitted paper.
3. DJournal supports a ranking algorithm for ranking the eligible reviewers.
4. DJournal provides an easier interface to help authors for submitting papers, and reviewers for receiving papers.
5. In addition, a novel hybrid decentralized system or HDS for diminishing the possibility of fake or fraudulent users (reviewer/author) from registration in “DJournal” is also discussed.

The remainder of the paper is organized as follows: “Related Work” features the state-of-the-art automated reviewing system. “Background” features some background information related to blockchain, smart-contract, and IPFS. “System model and implementation of DJournal” overviews the proposed system with a summary of the workflows is provided with the system design and description of different parts of our proposed decentralized reviewing system (DJournal). This section also includes the work methods of DJournal, Research field prediction mechanism using machine learning approach and demo application. A series of experiments with detailed result analysis is provided in “Result analysis”. “Discussion” section features the discussion over the implemented system, its limitations, and future modifications. “Conclusion” concludes the paper with concluding remarks.

RELATED WORK

Currently reviewing is the “most standard" process for any scholarly publication. Almost 90% scientist recommends reviewing is effective for the development and improvement in technological areas (Mulligan et. el., 2012, p. 132-161). Researchers and Scholars are getting their works reviewed by peers, which helps them to work further and gives room for improvement. Even with so much popularity, the process has many drawbacks including poor evaluation, personal conflicts, gender biases, stealing thoughts, etc. Thus, in recent years, people have attempted for a better and automated reviewing system. Besides the single-blind reviewing (Cho, Kwangsu & Schunn, 2007) and peer reviewing, modern computerized reviewing system can be categorized broadly into two (2) different categories including centralized and distributed.

Paper in (Cho et. el., 2007) introduces a centralized reviewing system. Here, the authors presented a web-based client-server application named SWoRD (Scaffolded Writing and Rewriting in the Discipline) and its working strategies. Authors in (Gehringer, 2001) introduced another web-based reviewing system for grading assignments of students. There were six phases from signing up to web publishing of the assignment. In (Kahani, Mohsen & Borchardt, 2017), authors discussed a way for exploiting a flaw in SMTP protocol to include email spoofing, and that can lead to manipulate the overall centralized reviewing system. They also suggested a solution for this kind of reviewing problem by introducing unique random ID to the authentic reviewers with their authentic email address.

Centralized web-based review systems in (Cho et. al. ,2007), (Gehringer, 2001) and (Kahani et. al., 2017) are prone to cyber-attacks thus compromising the security of the submitted papers. Cyber attackers could easily delete, modify, and update any kind of information or reviewing decision from the centralized system. They could also steal the research items and publish it elsewhere with their own identity. In addition, if a centralized server is destroyed, all information regarding submitted, reviewed and published researches may loss forever. Distributed review systems bear the same problems of being prone to cyber-attacks. However, it diminishes the possibility of losing information regarding reviewed or submitted or published research works.

Decentralized blockchain-based reviewing systems are a new addition to the automated reviewing system. In our previous book chapter (Rahut, Tanvir, Rahman & Akhter, 2019) we proposed a methodological framework for decentralized reviewing system using blockchain, smart-contract, and IPFS. The paper introduces three (3) sections – submission, selection, and review. The paper also introduces reputation-point as modified crypto-currency, which would be used as modified gas money (“What is Gas? | MyEtherWallet Knowledge Base,” n.d.) to find the eligible reviewer and to fuel the decentralized review process. Paper (Tenorio-Fornés, Jacynycz, Llop-Vila, Sánchez-Ruiz & Hassan, 2019) also directs toward a similar approach and proposes a decentralized reviewing system using blockchain, smart contract, and IPFS. Paper in (Jan, 2018) focuses on recognition and rewarding system for reviewers. In this system, authors can submit a punishment or a reward to reviewers according to their reviewing decision using blockchain.

However, the explained systems are in the theoretical domain and waiting for implementation. In paper (Avital, 2018), the authors presented a token-based payment system for reviewers using blockchain. Although, the papers in (Tenorio-Fornés et. al. 2019), (Jan, 2018) and (Avital, 2018) are discussed monetary value as a payment and similar things using crypto-currency but do not focus on the arise problems due to the monetary value including the attempt of bribing, or asking/offering money in exchange for getting favors in reviewing. Dishonest reviewers could find the public key of the author and ask for crypto-currency or authors could find out the public key of the reviewers and send some crypto-currency in exchange for favors. Having multiple user wallets or accounts for a person wouldn't create any problem during the uses of blockchain system in currency transaction purpose problems. However, in the case of blockchain based paper reviewing system multiple user wallets or accounts for a single person poses severe threats. While registering as a reviewer for a decentralized paper reviewing system, a person

(dishonest) can claim himself or herself as a higher rank expert and demands to have a large number of publications on a particular subject.
In all current blockchain systems, there is no perfect way of making sure that the information given during registration in the blockchain is true or not. This happens because of the interior structure of blockchain where multiple accounts of a person are possible but impossible to trace the multi-accounts holders. In our proposed system, this will create a major or dominating threat. One author-reviewer may have multiple review accounts with high-rank expertise and large publication numbers will influence our system to choose him/her as multiple reviewers and the situation becomes even more complex when he is the author of the submitted article. Author becomes the only (multiple) reviewers of his submitted paper. This will cause loss of credibility of the system, rise biasness and bring forth trust issues regarding the blockchain based peer-review systems.
The Papers by (Tenorio-Fornés et. al., 2019), (Jan, 2018), (Avital, 2018) and also our previous proposed model in (Rahut et. al., 2019) do not state or even discuss the above-mentioned problem or its feasible solution(s). Thus, in this paper we are going to extend our previous proposed research (Rahut et. al., 2019), using machine learning approaches for Tag prediction for finding eligible reviewers. Besides, we are proposing a novel approach for a hybrid decentralized system to diminish the possibility of fake or fraudulent users from registration (reviewer, editor, and authors) in this system.

BACKGROUND

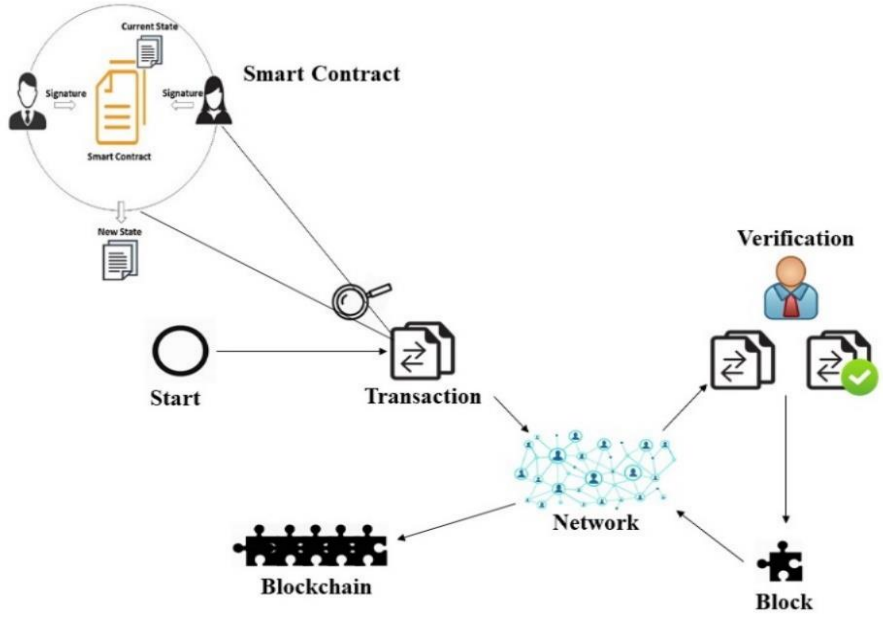
Blockchain

Blockchain is a special type of distributed ledger (shared database) with a set of distinct features including transactions that are verified by all network computers and stored information into a block. Blockchain guarantees the immutability of the ledger, as any form of modification in the block needs to manipulate every copy of the blockchain on the network. Any transaction that happens on blockchain is irreversible. There is no single point of failure in the blockchain. In a blockchain network, adding data into a block is considered as a transaction in the network. Every transaction in the blockchain network has a lifecycle and it is summarized below:

- A transaction is initiated by a node in the network. Thereafter the transaction is sent to the other participants of that network for the verification of that transaction.
- There are some rules to decide a transaction is valid or not. These rules are validated by the computers of the network.
- After the verification, the transaction is included in a block and a cryptographic hash is generated to sign that block. This hash generation process is also called mining. Cryptographic hash ensures the security of the block so that no one can tamper the inside data and thus keeps the immutability. After signing the block, it is broadcast to the other nodes in the network to verify if the block is valid against some preset validation rules. Upon validation, the node is added to the existing chain of blocks of the network. This process is done through the consensus mechanism. This mechanism is generally applied to multi-agent systems in a distributed process to make the system fault-tolerant. Unlike traditional databases, blockchain has no single authority to maintain the state of the ledger, so a public blockchain network must use a mechanism that can ensure the integrity of the ledger. There are multiple consensus mechanisms currently being used in different systems with different methods. The consensus algorithm that is used by the Ethereum network is called Proof of Stake (PoS) (Saleh, 2018). Due to consuming less energy to process transactions, it minimizes the cost of verifying network transactions. It states that higher value of the stake has higher right to add new blocks to the system.

- A transaction is processed, validated and added to the block with the participation of all the nodes in the network. It makes the system resilient and trusted as there is no involvement of any third party to tamper with data.

Fig 1: Life cycle of blockchain with smart-contract governing the transactions



Smart Contract

Fig 1. gives a brief idea about smart-contracts. A smart-contract is a feature provided by Ethereum blockchain. A smart contract can be considered a sophisticated node and an autonomous account of a blockchain network. This node can store data and execute pre-written commands autonomously based on certain conditions. This autonomous feature of the smart contract makes them a potential substitute for intermediaries. Therefore, intermediaries can be eliminated if smart contracts are used to execute a contract. We use Solidity language to develop our smart contract because it is the most used and effective language for developing smart contracts at present. The developed smart contract is deployed on the Rinkeby test network to verify its components, and for debugging purposes. This test network is also free to use. So, it is sufficient and appropriate to deploy the test run of the smart contract on Rinkeby. After the final development, this contract is deployed to the main network.

IPFS Technology

Storage in the blockchain network is very costly as the information replicates in the whole network. So, it is inefficient to store large files into blockchain. Inter Planetary File System (IPFS) (GitHub, 2019) is a technology where files are uploaded and generated corresponding hash codes. A file can be accessed by the network participants using its unique hash code. Thus, this technology is integrated with blockchain and brings effectiveness in the file storage.

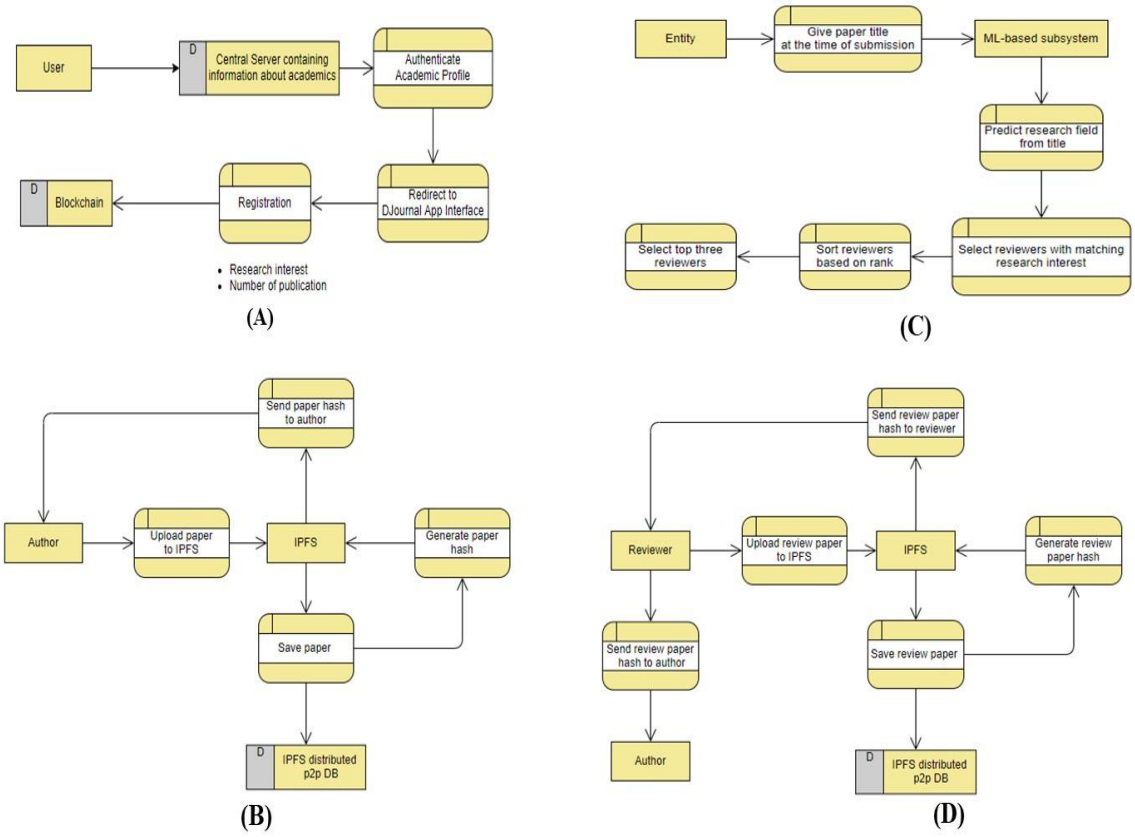
Keccak-256

Ethereum integrates Keccak-256 method (Keccak, 2019) to generate hash values. The input space for Keccak-256 is infinite and the output string is of 32 Bytes or 256 bits. All the blocks are connected and

secured by these hash values. This Keccak-256 method takes a large text or even files and encrypts them. Every file has a unique hash value and it uses to validate that no change is made to the source file. This hash function is used to sign the transactions in the Ethereum blockchain. Moreover, this function helps to make the chain secure so that no one can compromise the integrity of the platform.

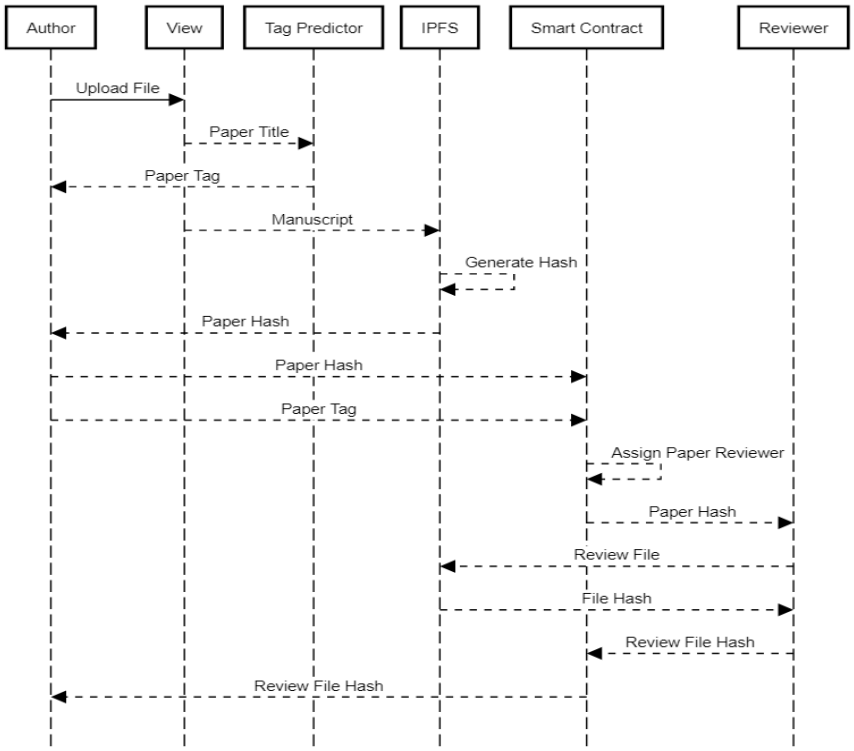
SYSTEM MODEL AND IMPLEMENTATION OF DJournal

Fig 2: Dataflow diagram of DJournal



The full system model of the proposed DJournal with its implementation threats and technical challenges are presented here. The system consists of two (2) kinds of actors including Author and Reviewer. A registered user can act as Author, or Reviewer, or both. The role of the authors is to submit papers for reviewing process. The role of the reviewers is to review a submitted paper. In our proposed system, there is no role for editor because it is played by the system itself. The system in fact works as an automated editor. The system finds an eligible reviewer based on a new algorithm proposed in (Rahut et. al., 2019). Thus, the complete paper reviewing system is divided into four different sub-sections including Registration, Submission, Selection and Review. Fig 3. presents the sequence diagram of DJournal.

Fig 3: Sequence diagram of paper reviewing process



A brief overview of the whole reviewing process is given below:

Registration

The whole system is implemented with a smart contract using solidity for backend and ReactJs for frontend or user interface. Backend of the application (DJournal) contains a smart-contract and it is written in solidity language. The frontend program is written using ReactJs. Anyone who wishes to use the system has to register first. The data flow for the registration process is shown in Fig 2(A).
The registration process needs to ensure that one person shouldn't have multiple accounts. Having multiple accounts can severely threaten the credibility of the reviewing system. In a situation, where someone uploads a paper from one account, and review the same paper using different account can direct towards a big security loophole. There is also another possibility of creating accounts with false information. Our proposed DJournal registration system adds a novel approach towards Hybrid Decentralized System or HDS, to bypass these two security loopholes of conventional decentralized systems. It includes a centralized gateway website that is responsible to open a user account with their educational institute's mail id and all the required fields including research interest, publication number, Google scholar link, and etc. After getting confirmation from the gateway, the user is redirected to the decentralized application's webpage, in this case, the interface of the paper review/paper submission system described. Thus, HDS implementation in registration improves the security of the system.

Submission

The workflow of the system begins with the act of submitting a paper to the system for reviewing purpose. Large file transmission in blockchain is very costly, thus a new associative framework IPFS (Inter Planetary File System) is integrated to handle the large files. A user, who wishes to submit a paper, can submit papers via the client-side application. The application grabs the selected file and uploads it to IPFS. Thereafter, IPFS then returns a hash string which is a downloadable link for the uploaded paper. The link is then sent to the smart contract through the user-interface. The client-side application then takes that link and sends it to the reviewers inside the system with the help of blockchain and smart contract. A dataflow diagram explains the flow of data throughout the paper submission process in Fig 2(B). The paper also introduces a new sub-system based on machine learning for selecting and sending the paper to an eligible reviewer.

Selection

A Reviewer is deemed fit for doing a review if he or she has -
1.Same research area as the submitted paper.
2.Number of published papers on that particular research-area.
The system selects the best possible reviewers to review a submitted paper automatically based on the algorithm proposed in our previous work in (Rahut et. al., 2019). The system tries to match the research domain of the submitted paper and the research domain of the users of the system. To do that, the system collects the research domain and publication numbers from a user (Reviewer) at the time of his or her registration process. The system with the help of the sub-system collects the research domain of the submitted paper automatically from the paper title. The sub-system predicts text-based tags from the paper title given by the author at the submission time. Later, these tags are used to find an eligible match from the reviewer's information. If there is a match, the system then sorts the matched users (Reviewers) based on their number of publications on the specific research domain.
The first three eligible reviewers are ranked using the ranking algorithm based on Eq. (1). The reviewer is selected based on same research domain as the submitted paper, and larger number publications on the field.

$$R\gamma = \sum_{\varphi=1} (NP\varphi + RP\varphi) \ * RS\gamma \tag{1}$$

Where,

$R\gamma$ = Rank of the γth reviewer

$NP\varphi$ = No. of publication at φth instance

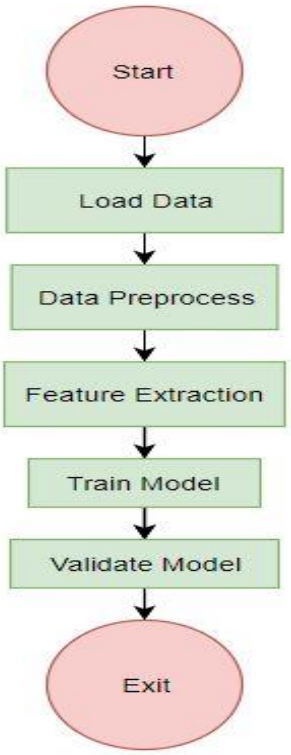
$RP\varphi$ = Reputation point at φth instance

$RS\gamma$ = Review Status of the γth Reviewer

A user of DJournal, who is willing to review a paper, may choose "active" or "busy" status. If someone chooses "busy" status, his or her total no. of publication and reputation points will be multiplied by 0 (zero). Thus, busy reviewers will get the lowest rank and thus won't be selected as reviewers. If someone chooses "active" status, his or her total no. of publication and reputation points will be multiplied by 1 (one). Thus, he or she will be ranked according to his or her capability. If the system sends a review request to an unwilling user and he or she does not respond by either accepting or rejecting, the review request will hang there for an indefinite time. This modified algorithm ranks only those users who are willing to review as reviewers. This whole process is done automatically by the system with the help of a developed smart contract. As, in this system, the smart contract selects the reviewer, and thus it acts as smart editor! Fig 2(C) illustrates the reviewer selection process using a dataflow diagram. Fig 4 illustrates the research domain prediction subsystem model. The dataset includes 20000 research paper titles with keywords. They are labeled based on their keywords. The model uses 80% data for training and 20% data for testing. Data are first pre-processed using Tokenization, Lemmatization, and Stop word removal

techniques. Punctuation marks are also removed. Then using the Tfidfvectorizer, features were extracted from the processed data. Tfidfvectorizer follows the bag-of-words model, and it is a very common method of feature extraction. The extracted features are fed into the ML algorithms for classification purposes. After training, the model is able to predict the class of a newly given paper title. After completing the research field prediction process from submitted paper title, the predicted research field is used for ranking potential reviewers according to an algorithm represented by Eq. (1).

Fig 4: Proposed model of research field prediction from submitted paper title using machine learning



Review

The last part of the workflow is the review process. After the Reviewers are selected by the smart contract (sub-system), they receive the download link from the IPFS. The reviewers then download the paper. Then they review it. After successful reviewing, they submit their review report(s) using the similar technique of file submission with the help of IPFS and smart contract. Fig 2(D) explains the data flow inside the system throughout the review process. The smart-contact mentioned earlier is responsible for sending the reviews to the authors automatically right after the reviews have been submitted.

Demo Application of DJournal

An application is created with Solidity and ReactJs for experimenting with the accuracy of the proposed framework. The sections provided in Fig 5 will try to give a view of the developed application based on the proposed framework. The whole application has five (5) different sections. The upper left section presents the user registration form. Interested researchers can become a user of the system by giving the research interest in the “Tag” marked box and total number of publications in “Number of publication” marked box. The upper right section of the application is used for submitting a paper for the review process. First, the title of the paper needs to place in the "Paper Title" box. The research domain is selected using the

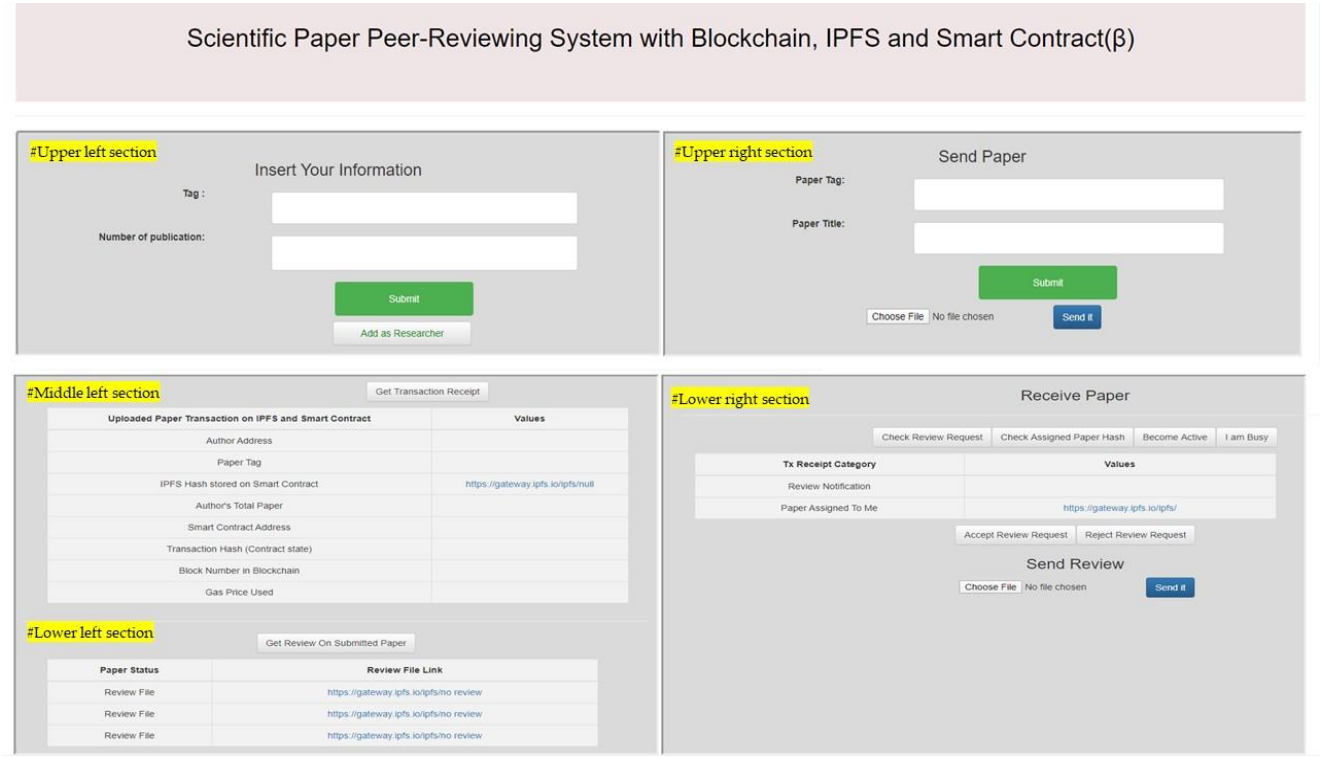
research domain prediction mechanism using machine learning of that uploaded paper and inserted into the "Paper Tag" box. After that, he or she presses the "Submit" button. Then the user taps on the "Choose File" button, he or she can then select a paper to upload. After everything is taken care of, he or she presses the "Send it" button places a transaction. The developed smart contract for this system selects Reviewers based on the matching of the research domain with the submitted paper and the number of publications. Selected reviewers will then receive the download link of the submitted paper.

The lower right section is the part where Reviewers can choose to accept or deny the reviewing request of a submitted paper. A user can press the "Check Review Request" button to check if the system is asking him or her to review a paper. He or she can accept the request for reviewing the paper by pressing "Accept Review Request" or reject/deny the request by pressing "Reject Review Request". Reviewers can also choose active or busy status by clicking “Become Active” or “I am Busy” button. If the Reviewer accepts the review request for a submitted paper, he or she then can collect the downloadable link of that paper produced by IPFS, by clicking “Check Assigned Paper Hash”. After the review, the Reviewer can submit his or her review comments as a file. He or she can select the file by clicking “Choose File” then press ‘Send it” to send the review directly to the author of the submitted paper through a transaction.

The transaction is governed by the developed smart contract for the system. The Author who has submitted a paper for reviewing can check the review of his or her work. The lower-left section of the application is dedicated for that purpose. If the review is sent by the reviewers, by clicking the "Get Review on Submitted Paper" button, the user can see the download links of the files containing review comments.

The middle left section of the application is used for viewing necessary and associated information of the submission. After submitting a paper for reviewing, the user can see his or her own Ethereum address, research field of the paper (paper tag), IPFS generated hash code of the submitted paper, his or her total number of paper, address of the smart contract (address of the genesis block where the contract is stored), transaction hash, current number of blocks in the blockchain and the price of the transaction (gas price) [11] in ether by clicking “Get Transaction Receipt”.

Fig 5: DJournal application interface

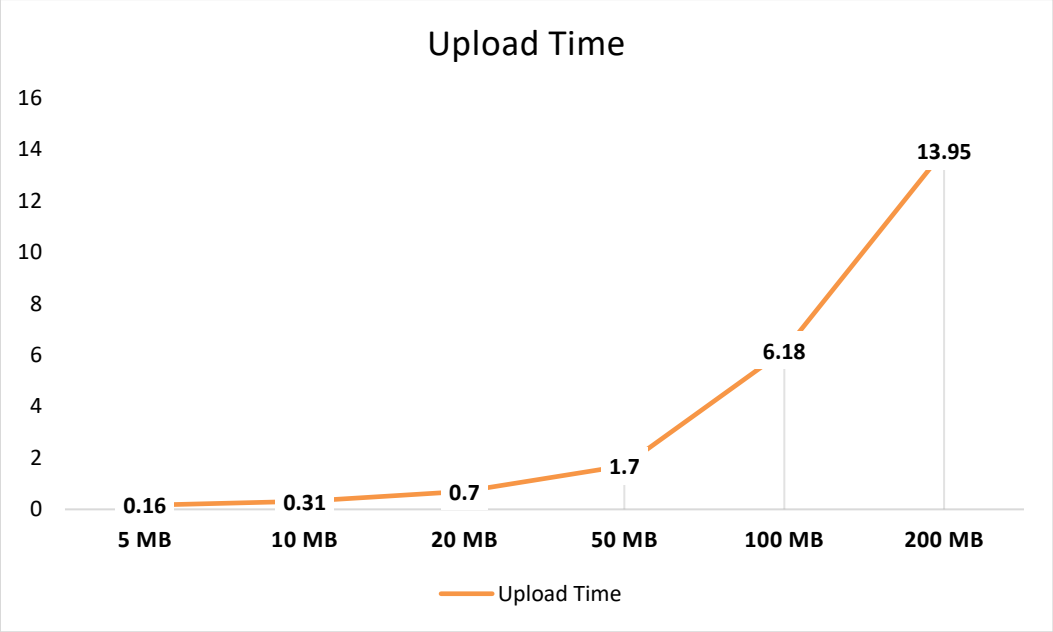


RESULT ANALYSIS

Testing Submission Process (Paper Submission and Review Submission)

The system uses IPFS as a distributed database. Uploading and downloading papers from IPFS are two major tasks of the system, thus performance of IPFS is very crucial. We tested the load on the IPFS network and it showed promising results. Different sizes of files were uploaded to IPFS and their uploading time was measured in seconds. It is usual to submit research papers in Latex, pdf, doc, docx, etc. format, for reviewing. DJournal also supports these conventional file formats. Research paper files of these formats usually from 5MB to 20MB size. Fig 6 presents that it takes 0.16-0.7 seconds for uploading files of such size. So, the proposed system gives a good performance in its main task of submitting a paper for review by the author and submitting a review by the reviewer. The experiment was done using a machine with Intel 7th gen core i7-7500U processor, and 8GB ddr4 RAM.

Fig 6: Upload time on IPFS



Testing Machine-Learning Based Automatic Reviewer Selection-

The newly proposed ML-based subsystem for research field prediction is very important for making automation in the process of reviewer selection. Fig 7 shows the comparisons between Gradient boosting, Multi-layer perceptron, Naïve Bayes, Support Vector machine, and Logistic regression algorithms in terms of precision, recall, f1-score, and accuracy. This experiment was done using a machine with an Intel core i7-8700K processor and 16GB ddr4 RAM. It is clear from Fig 8 that Multi-layer perceptron gives better results in the case of research domain prediction.

A Multi-layer perceptron gives a score of 77% in precision. Precision directs to the ratio of correctly predicted observed class and total predicted observed class. Higher precision leads to a lower number of false positives. Recall is the ratio of correctly predicted positive observed class and total positive observed class. Higher recall leads to a lower number of false negatives. F1-score is the weighted average of precision and recall. Accuracy is the ratio of correctly predicted between observed class and total

observed class. In this case, Multi-layer perception shows the highest precision. It means that the model based on this algorithm will perform well in case of correctly guessing the research domain from a paper title.
A little mistake in title increases the chance of predicting the wrong research domain for the paper. Thus, the chance for finding the perfect reviewer with a matched research domain will also be decreased and this is the main concern of DJournal. So, having higher precision makes a multi-layer perceptron best suited for the task.
Fig 8 presents the accuracy of Multi-layer perception for different amounts of data and it is clear from that more data will give more accuracy. Thus, the model not only handles more data but also able to perform better with a larger volume of data. It also illustrates that the improvement of accuracy becomes non-linear when more than 4000 data are used. Though the accuracy keeps improving, due to the non-linearity of the graph, it can be safely assumed that the rate at which accuracy is improving will drop in near future. In future, better models with new approaches like deep learning could pave a way for a higher rate of accuracy.

Fig 7: Comparison of different ML algorithms for research field prediction

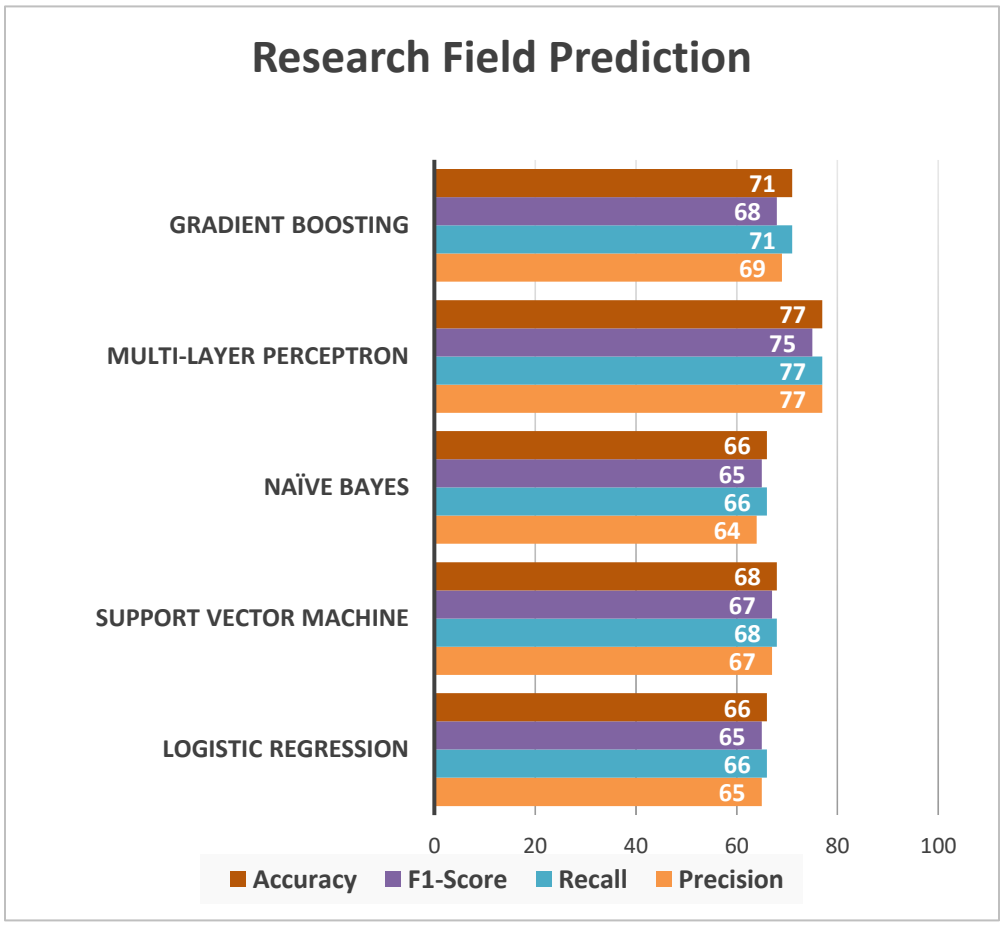
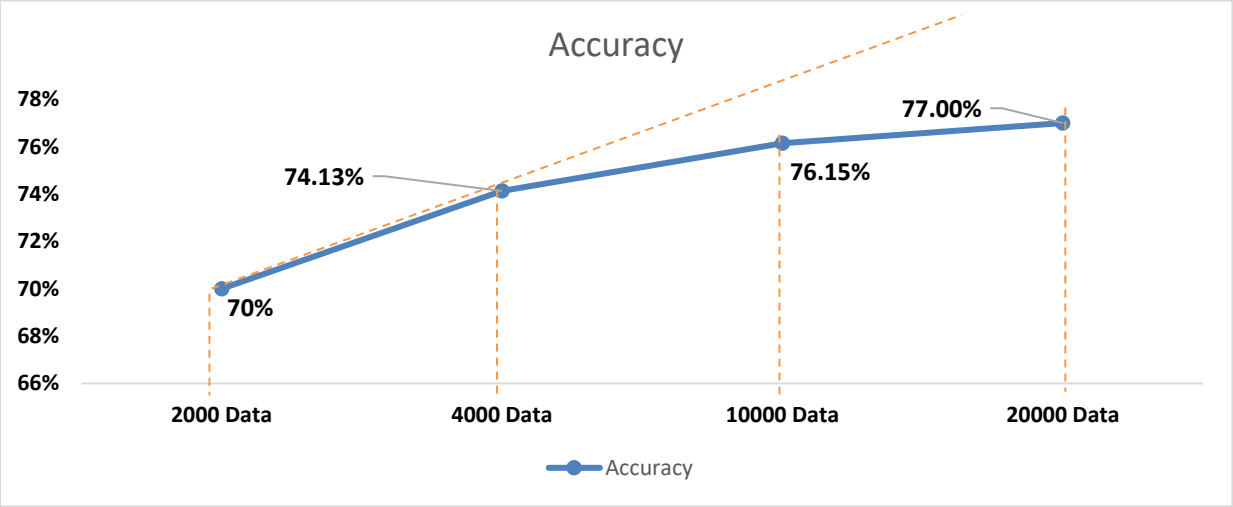


Fig 8: Multi-layer perceptron accuracy vs data-size



CONCLUSION

Creating an unbiased, anonymous and autonomous paper review system can affect scientific society greatly. Biased review, idea heist, and etc. can gravely injure the scientific community and withheld progress of civilization. This article successfully proposes and implements a decentralized paper reviewing system DJournal with autonomous Reviewer selection based on a ranking algorithm and machine learning-based research field prediction. This article also finds out two (2) security loopholes on decentralized systems and proposes a novel HDS (Hybrid Decentralized System) approach to solve the security issues. The article also suggests the modernization of DJournal by addressing the recommender system. Thus, the article investigates, experiments and instigates decentralization and automation with the help of blockchain and machine learning based paper reviewing. In future the system can be improved as a recommender system for recommending Reviewers to choose an article for reviewing. Authors can also provide rating (on 10) of a submitted article according to their research domains and reviewers can also provide his/her choice rating during his registration. The system can also auto-track each Reviewer engagement (likes/comments/preferences) with various articles, and thus the system will have Reviewer choice profile vectors and the article vectors, and these vectors can be used to predict which articles will be similar to the reviewer's taste. Therefore, along with new articles in a week, a separate recommendation can be made to a particular Reviewer based on the articles which he hasn't read already.

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