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# A Modernized Voting System Using Fuzzy Logic and Blockchain Technology

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***Abstract***—Voting is a formal expression of one's choice. Though the process is simple, it has far-reaching and deep-lying impacts. Through a vote, people get a channel to voice their opinion anonymously. There are issues with the orthodox traditional voting system, which is used across the world today. Studies, presented throughout the paper, would highlight how millions of people have missed out on voicing their opinion, or get proper representation, due to the many short-comings of the dated traditional voting systems. Blockchain is a comparatively new technology. There have been advances and research made to make use of blockchains in the world of finance and ledger management. But precious little has been done to tackle simpler but wider-reaching problems of voting. The novel approach suggested here would give the voters a chance to vote from the comfort of their homes, or, without adjusting their busy everyday schedules, and make sure everyone gets a proper representation as well. A combination of blockchain technology and fuzzy logic has been used here, to achieve a solution, that we think would help modernize the voting system and ensure greater satisfaction among the voters that their views have been represented in one way or the other. Using this novel approach, we believe that more people would be encouraged to vote and a greater number of voices would get proper representation.

***Index Terms***—Blockchain, Fuzzy Logic, Voting, Weighted Voting, e-Voting, Online Voting.

## I. Introduction

There has always been a very low turnout of voters on election day. Statistics shown later on in the article would show that even in most developed countries, more than 30% of the eligible voters don't cast their votes due to one issue or the other.

Another problem with the existing voting system is that the voters are able to cast just a single vote. Instead, if the voters were given an option of ranking the candidates by their choice, as to who is more likely to support their cause and opinions, possibly, one of the other candidates would have been a better choice, satisfying a greater number of people.

Technology is the solution to most problems if not all, in today's world. When e-commerce to house hunting can all be done online, a secure voting structure should not be out of reach of technology. The purpose of this paper is to cater to the two aforementioned problems and provide a constructive technical solution to address the same. The methodology would enable more eligible voters to vote for their candidates and enable them to rank the candidates from best choice to the worst, so that, on aggregate, the candidate who is more likely to help a greater number of people, or whose agenda aligns with the demands of a greater number of people, is elected the winner.

The main objective of this article is to provide a novel way to address and mitigate these major limitations and blockades in terms of the traditional voting process. There have been solutions provided in the past to introduce e-Voting, like in CAWI[15] and TrueVote being tried in the past, in some constituencies of Paris, London, Italy, and Finland with varying degrees of success. They were however curtailed in favor of the traditional voting system, owing to certain limitations and their vulnerabilities of a typical centralized system[16].

In this article, the objective is to make use of decentralized technology like blockchain and changing the traditional voting process using fuzzy logic, to address the problems of why people do not vote and how to make voting more secure. It is a two-pronged problem, which would essentially require a two-part solution, as would be explained through the course of this article.

## II. Materials And Methods

### The Problem

The first part of the problem is related to low voter turnout. There can be multiple reasons in today's practical world, why one may be unavailable on a particular day, be it due to the work, or illness, or simply

 

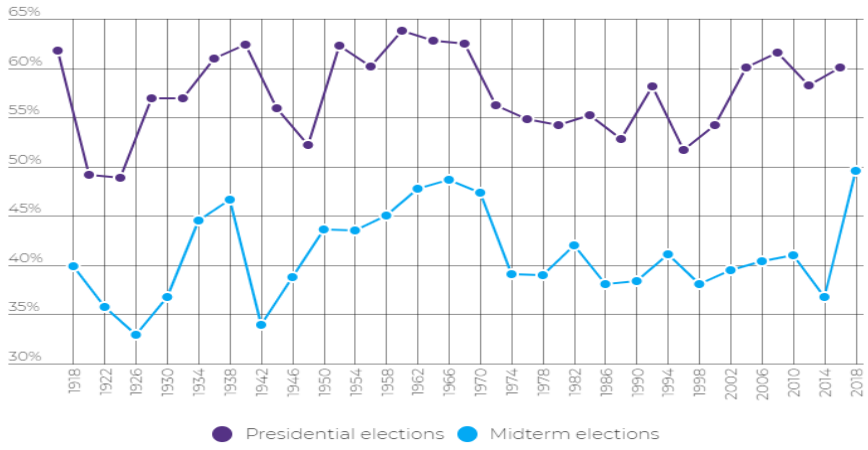


Fig.1. US Voter turnout statistics 1918-2018

lethargy to go out and stand in a queue to cast the vote. Let's take the UK for example. During the election day of 2019, there were innumerable reports of people having to stand in long queues for over half an hour to one hour, just to cast a simple vote. In the UK, the voting day is not declared a government holiday. So, those who even decided to turn up to vote had to miss some part of their day's work, face the trouble of going to and from the polling station, and stand in the queue to cast their vote. In countries like India, people polling days are generally declared a government holiday, so that people can take the time out to go to the polling station and cast their vote. This leads to the government offices and businesses losing tremendous amounts of money, simply because it is an election day, which is unacceptable.

The statistics for the US elections (as shown in Figure 1, sourced from [8]) over the years, it would paint a picture that despite being one of the most advanced countries in the world, the highest voter turnout has been 64% in the last 100 years. This means, more than 1/3rd of the eligible never cast their votes per election. That count of missed votes was close to 100 million in the 2016 presidential elections. If we take the example of another such advanced country, the UK, voter turnout there has been woefully low as well (as shown in Figure 2, sourced from [9]), with the last 2019 General elections registering for just 67.3% votes. This means, close to 1/3rd of the eligible voters did not cast their votes.

Besides these, there are the obvious concerns of rigging, wrong votes, and people not being able to reach the polling station due to multiple socio-economic reasons. There is also the chance of human error when counting the ballot. There is also the obvious problem of infrastructure. To organize an election, each government has to spend huge sums of money to buy equipment, organizing polling stations, getting postal services, employing people to preside over polling stations, employing people to count the ballot, etc. According to reports, the UK General election in 2017 cost the government just over £140 million.

The second part of the problem is with people not being able to select the most suitable candidate aligning to the views and opinions of the most percentage of people. For example, say there are 3 candidates (A, B and C) in a constituency and the voter has to select just 1 of the 3 in the present-day voting system. Let's say 40% of voters would vote for Candidate A, 25% for candidate B and 35% for candidate C. The clear measure says candidate A is the clear winner when that candidate was not the choice of 60% of the voters, leaving them disgruntled and disillusioned about the voting system.

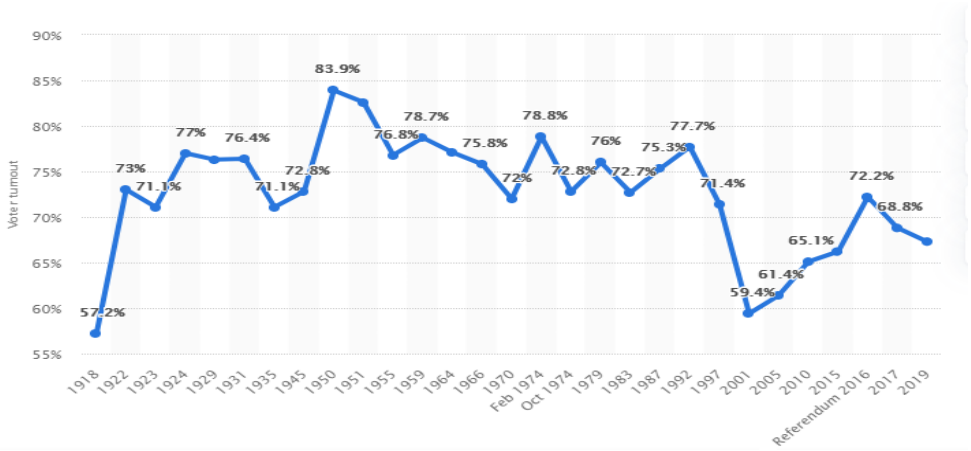


Fig.2. UK Voter Turnout Statistics 1918-2019

## Literature Review

The basic concept of the blockchain architecture and its implications and utilities were referenced from [4, 5, 7]. Here, the authors discuss this new technology of blockchain and its many abilities in theory. Despite lacking a practical implementation, these articles go into a good depth to explore the very essence of how powerful and widely utilized this blockchain technology can be if used to its fullest extent.

An approach to resolve the discussed concerns using blockchains was attempted in [1]. But there is a problem with this approach. Here, there are multiple blockchains being used, each candidate having a blockchain of his/her own. While the approach suggested is a good one, there would be a few concerns with this. There is no limitation to how many candidates there can be in a constituency.

If we take the example of the largest democracy in the world, India, and check the data gathered from [10], we would see that there are 543 constituencies, with each constituency having an average of 14.8 candidates. This would mean, there would be 8037 blockchains needed. To validate if the voting has been fair or not, people would have to subscribe to all the blockchains, which would be impossible. A resolution to this problem would be discussed and implemented in the implementation section of this article.

A variant discussed in the referred articles [2, 6] would come in handy to solve the issue at hand. Here, the authors discuss how the encryption would occur and where the resolution of the voting would take place. It is also discussed how the voters would keep their vote secure and how they can actually validate whether their vote has been made eligible as part of the chain or not.

To solve the weighted part of the issue, whereby, the voters are able to rank the candidates in order of who would most likely resolve their issue, we look to the fuzzy logic implemented in [3]. From here, we can take a look at the fuzzy logic part of the solution provided and implement our own solution making use of the concept of the fuzzy weight that has been discussed in the paper. The objective of introducing fuzzy logic to the entire mix of voting and blockchains is to prevent scenarios where candidates can easily manipulate the number of votes they need, to get to a numeric majority. Rather, the weighted fuzzy voting system, through the ranking of the candidates by the voters (via their votes), would actually enable the candidates to cater to the problems of more people rather than just a numeric majority.

We envision that a combination of the voting using weighted logic and using technology like blockchain would resolve most if not all such concerns.

As the issue at hand is a two-part problem, to solve this problem, a combination of fuzzy logic and blockchain technology would be used. We would be discussing the utility and implementation of each of these two technologies in detail after the overview has been provided. The below algorithm provides an overview that is represented in Fig. 3.

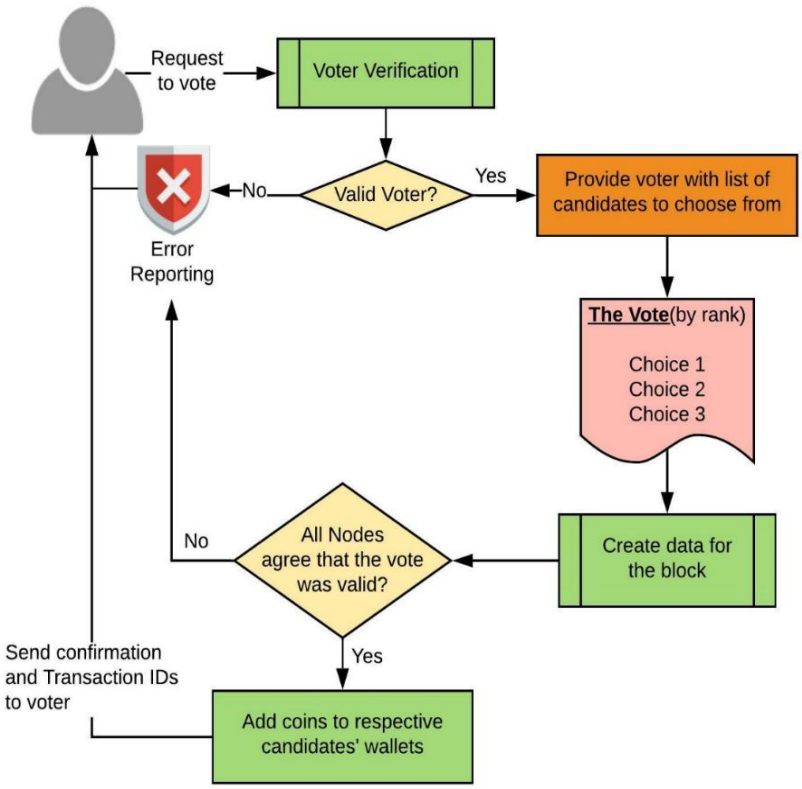


Fig.3. Flow of system control for the proposed voting mechanism

 

**Algorithm**

Step 1: Voter logs into the voting application

Step 2: The validating system validates if the voter is a valid one and has not yet cast his/her vote

Step 3: If the voter is valid, go to step 4. Else, show an error message to the user.

Step 4: Identify the constituency of the voter

Step 5: Voter is provided with a list of candidates from his/her constituency

Step 6: The voter selects which are his/her top three candidates and ranks them accordingly

Step 7: Use fuzzy logic to determine which candidate would receive how many coins

Step 8: Create a record of each of the three transactions for the constituency blockchain and get it validated by all participating nodes

Step 9: Are transactions valid? If yes, go to step 10. Else, show an error message to the voter

Step 10: Transfer the calculated amount from Step 7 to each of the candidates

Step 11: Record the transactions in the constituency blockchain

Step 12: Pass the transaction IDs and a confirmation message to the user.

**Out of Scope for this article**

As there is a multitude of technologies out there for secure user validation and authorization of the user, this segment is being considered as out of scope for this article, to keep it brief and focus mainly on the fuzzy logic and blockchain aspects of the proposed model. The user needs to log into the system with credentials provided by the election commission.

For the second level of validation, the voter needs to give access for the camera on the device to the application. The photo of the voter is sent to the election commission and they can authenticate if he/she is the valid person using the credentials, using facial and pattern recognition.

Once authenticated and determined as valid, the election commission can send back the list of available candidates to the voter to choose and rank from. Once voted, the same would be recorded and the voter would not be allowed to vote again.

## III. Technologies And Implementation

**Blockchains**

As has been explained in the section above, we would be making use of the weighted logic to identify how many points are to be assigned to which candidate. Every voter would be given a digital wallet and each of the candidates would also have a digital wallet. Each voter, when allocated the voter ID, would get $\sum Wi$ (with i = 1 to 3) coins in his/her digital wallet.

There would be no way of transferring the coins to a candidate other than programmatically. Once the vote has been cast and the points decided using the logic explained in section III, the points would be used to issue coins from the voter's wallet to the candidates' wallets programmatically.

For each of the candidates chosen, there would be one transaction. The number of coins transferred to each candidate would be equal to the number of points derived using the fuzzy logic explained in section III. The transfers are made and a block is created with all of the transaction details. Each block of the blockchain would equate to a single vote. This block is then sent out to all the nodes to verify if it is a legitimate block. If everyone's response is positive, all the nodes update their blockchain with this new vote. If there is an issue, the block is rejected and the transactions rolled-back.

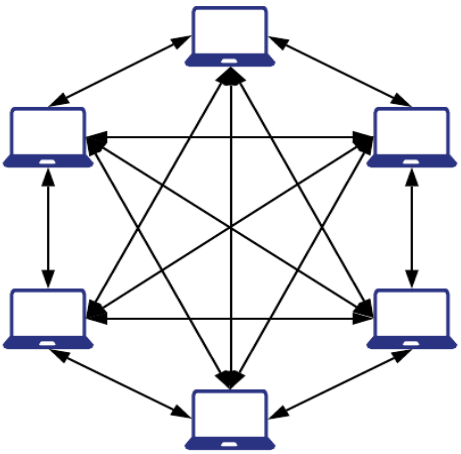

Fig. 4. Blockchain Nodes interacting with each other

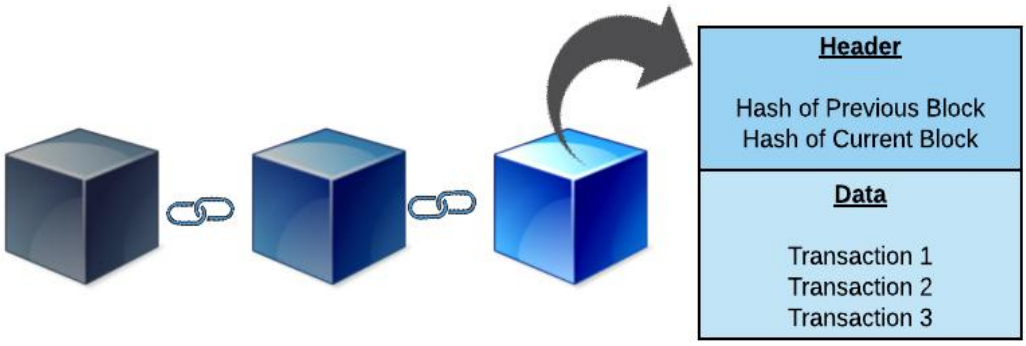


Fig. 5. Contents of each block in the chain

In the proposed design, each block would hold:-

a. The Header consisting of the hash of the previous block and the hash of the current block
b. Data consisting of voter transactions (3 transactions, each of a different amount).

Because of the inherent security that is brought by the hashing concept and the blockchain validation done across all nodes, the votes cannot be tampered with and all vote transactions would be kept secure for validation. The results and observations of this implementation would be discussed and dissected in the later sections.

**Fuzzy Logic**

In the approach that is being suggested, the voter would be getting the option to rank the candidates in his/her constituency, based on how likely they are to fulfill the voter's needs/demands. For this, once the validations are done by the validating system/service described previously, the voter would end up with a list of candidates to choose and rank from. The voter would then rank the top 3 candidates and the fuzzy processing logic at the backend would be triggered.

There would be pre-determined weights assigned to each of the positions/ranks assigned by the voter. These weights would be consistent throughout all the constituencies, to ensure fair voting and ranking. Let us say, that the weight for each of the ranks is Wi, with i being the rank determined by the voter for the candidate. Then, the total number of coins sent out by the voter would be $\sum Wi$, with i=1 to 3.

Previously, the candidate would have simply aimed to get just a numeric majority of the voters in their favor. Instead, using a fuzzy weighted logic would always force the candidates to cater to most, if not all of the voters, in order to win the election.

For traditional voting, the total votes received by a candidate would be the number of voters who voted just for him/her as Rank 1. The total available points from ranked voting would be

$$\textit{votes received by a candidate} = \sum \textit{( (number of voters in a rank) * (weight of that rank) )} \quad (1)$$

If the results from the vote bank are to be analyzed, we get the below results as displayed in Table 2.

The results and observations would be discussed in the later sections.

**Proposed system's compliance with basic voting principles**

There are some basic principles to voting and if the proposed system is to replace the traditional voting system, it should comply with those principles as well. We would chart below, how the proposed system would comply with those principles:-

1. Privacy – Secret Ballot

The current voting system has the process of a secret ballot, using which, the people can cast their vote and no one would ideally know who the vote was cast for. The proposed system makes use of cryptography in blockchains to ensure the voter's privacy. The voter's hash is stored in the system and can be used to verify that the vote has been cast by the voter, but the vote cannot be retrieved or be modified

2. Eligibility to vote

The current voting system has the process of checking in the system whether the person is eligible to vote, per the electoral register and if the person meets the desired criteria and has not been disqualified otherwise. The proposed system aims to make use of the same principle and system to verify the voter, per the voter registry and also validate if he/she has not already cast his/her vote this term.

3. Verifiability

The current voting system has the process to verify whether the person has cast his/her vote. The same is updated in the voter registry and people are given a mark in their finger using ink, to suggest that they have already voted. Our proposed system wishes to make use of a digitized system to do the same. The voter, once he/she has cast his/her vote, would be given a receipt to show that the vote has been successfully cast and that it is part of the blockchain. Also, an additional step is that the voter's hash would be stored in the blockchain for future validation that the vote has been cast by the person. However, to ensure voter safety and security, the vote itself would not be revealed.

**Addressing online voting security concerns**

There are obvious security concerns that need addressing when it comes to online voting. There are three levels of security that would be implemented in the system:-

a. Login and authentication if the voter has already cast his/her vote
b. Security of the Blockchain and how it would fend off potential hackers from manipulating the data.
c. Maintaining the anonymity of the voter

*Login and Authentication of a voter*

As had been previously mentioned in this article, there are numerous applications and systems out there, which can be used to authenticate the validity of a particular voter and his/her right to vote, and hence, has been kept out of the scope of this article. A simplistic, yet robust approach would be, a two-part authentication. First, the voter would log in using the credentials provided to him by the electoral council at the time of registering to vote. The second step would be giving access to the laptop/mobile camera and the system would basically do facial recognition using the photos in the election council database.

 

Table 1.(a) to (j) Demonstrates how 10 voters have voted for the example

| Voter: John | Candidate |
|---|---|
| Rank 1 | A |
| Rank 2 | D |
| Rank 3 | E |

(a)

| Voter: Sam | Candidate |
|---|---|
| Rank 1 | B |
| Rank 2 | D |
| Rank 3 | E |

(b)

| Voter: Matilda | Candidate |
|---|---|
| Rank 1 | A |
| Rank 2 | D |
| Rank 3 | E |

(c)

| Voter: Ron | Candidate |
|---|---|
| Rank 1 | A |
| Rank 2 | D |
| Rank 3 | E |

(d)

| Voter: Terry | Candidate |
|---|---|
| Rank 1 | C |
| Rank 2 | D |
| Rank 3 | B |

(e)

| Voter: Tom | Candidate |
|---|---|
| Rank 1 | B |
| Rank 2 | D |
| Rank 3 | E |

(f)

| Voter: Gina | Candidate |
|---|---|
| Rank 1 | B |
| Rank 2 | C |
| Rank 3 | D |

(g)

| Voter: Vasquez | Candidate |
|---|---|
| Rank 1 | A |
| Rank 2 | E |
| Rank 3 | D |

(h)

| Voter: Linda | Candidate |
|---|---|
| Rank 1 | D |
| Rank 2 | E |
| Rank 3 | C |

(i)

| Voter: Pam | Candidate |
|---|---|
| Rank 1 | E |
| Rank 2 | D |
| Rank 3 | B |

(j)

*Security of Blockchain against hackers and spoofing*

As has been discussed in [13,14], blockchains have inherent security measures that help prevent spoofing, tampering and otherwise altering the data. Blockchain is, as the name suggests, a chain of blocks.

Each Block would hold a hash of the current block, a hash of the previous block, the timestamp of when the block was created and the data, or, transaction details. When a hash is created, it is created over all of the contents of the entire block, including the hash value of the previous block. The blockchain as a whole is redundant and stored in all of the participating nodes. The chain is constantly validated to ensure that the correct chain is always being used. So, if all of a sudden, someone changes a block, the hash in the trailing blocks would not match-up. The entire chain would be considered corrupt and the copies from the other nodes would be made use of.

So, in effect, if someone with malicious intent wants to change the data, in say block 235 of the chain, he would have to change the transaction details of block 235 and generate a fresh hash for the block. But, if that happens, the hash value in block 236, which holds the hash of 236 would also change. If that is hacked and corrected, the hash value in 237 would also be corrupt now and so on and so forth, unless the entire chain is changed, which is near impossible.

If we assume that theoretically someone succeeds in changing all of the nodes in the chain, which would require huge amounts of computing power, the hacker would have succeeded in changing just one node. Blockchain technology says that at least 51% of the participating nodes would have to agree on whether a chain is valid or not. So, the hacker would then have to hack and modify the nodes and chains in at least 51% of the nodes. Else, the tampered blockchain would be disregarded as invalid. This is a near-impossible task.

*Maintaining the anonymity of the voter*

For the purpose of security of the voter, and to uphold the rule of the secret ballot, the system must ensure that the identity of the voter stays anonymous. This is ensured by the way the voter details are stored in the blockchain. Each user/voter of the blockchain has two keys. One is a private key and the other is a public key. The public key is available to all nodes and is used to validate whether a particular transaction or block or vote, in this case, is valid or not. Using the public key, the voter's details cannot be established as the voter details are encrypted using SHA-256 hashing encryption. The private key is always secure with the voter. Only and only the voter would have access to his/her own private key. It is not a system generated token. It is something that the voter sets for himself/herself. This key can be used by the voter to validate whether he/she has cast his/her vote correctly and to validate if his/her vote is being counted. No one other than the voter would be able to see the origin of the transaction. All a third person would see is the hash of the voter's address being the origin of the transaction, the hash of the candidate's address is the destination and the amount that was transferred.

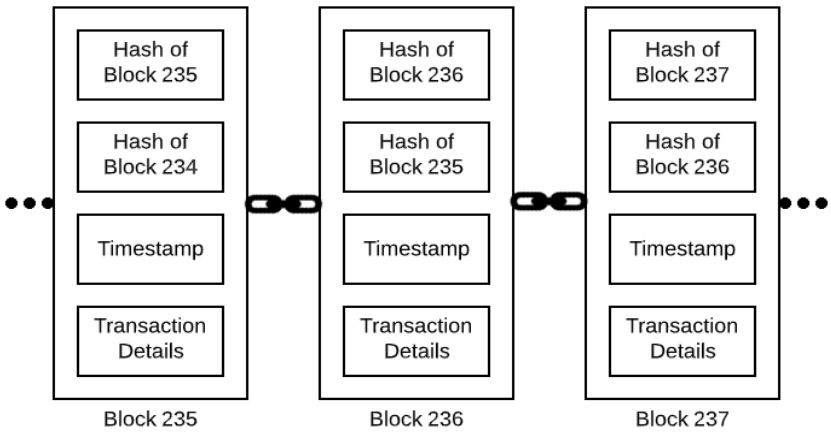


Fig. 6. Hashing mechanism imparting security to blockchains

***The merit of a combination of Fuzzy Logic and Blockchain Technology***

The novel approach that has been suggested here is aimed at overhauling and addressing all of the issues and concerns that were there with a traditional voting system.

Let's suppose only the fuzzy logic approach was suggested, voters would be given the option to select and rank their candidates of choice rather than having to select just one. But, then again, voters would still have to go to polling stations and all the issues related to manual voting, discussed previously in the article, would still persist.

Now, on the flip-side, if we consider only the blockchain technology was used, people would gain the advantages of a secure online voting system, using the best technology out there for the same, and all of the advantages that follow. But, the issue with the traditional voting process of having to select just one would still persist. Voters would then loose out on the option to have a choice of ranking by which, from a big-picture view, a candidate would be elected, who would be able to cater to a greater percentage of the voting population.

Voting is sensitive and, at the same time, a critical topic has almost never evolved. The reason for this being, people would always refrain from changing something that would have such a mass impact and carry huge risks at the same time. This is why, despite being unrelated to each other technically, it would make sense to implement a combination of both of them together, in the approach suggested in this article, so that most if not all voting process-related concerns can be addressed in one go.

## IV. Case Study

### Weighted Voting Case Study

For a case-study, we would consider 5 candidates – A, B, C, D, E and that the election commission has decided there would be 3 weights to the ranks provided by the voter. For the first rank (W1), the weight would be 3. For the second(W2), the weight would be 2. And the third (W3), the weight would be 1.

Table 2. Comparison between traditional voting and ranked voting results from Table 1 data (Weighted Voting Observation)

| Candidate | Traditional Voting | Ranked Voting (Points) |
|---|---|---|
| A | 4 | 12 |
| B | 3 | 11 |
| C | 1 | 6 |
| D | 1 | 19 |
| E | 1 | 12 |

The detailed data from the case study of weighted voting are displayed in Table 1. These would be discussed in section V in detail.

### Blockchain-based Online Voting Survey

In this section, we would be discussing the observations from the comparative study between the traditional voting process and blockchain voting explained in section III. We had asked 40 people and explained what the new technology can do for them and how it would be secure to vote using this method. Then, we conducted a study of who would want to move to this new voting system, and who would prefer to continue going to polling stations and vote the traditional way.

The detailed data from the survey are displayed in Table 3. These would be discussed in section V in detail.

Table 3. Survey result of whether people would want to use a blockchain-based online voting system VS a traditional ballot system

| Opinion | Number of people | Percentage of people |
|---|---|---|
| Yes | 31 | 77.5% |
| No | 3 | 7.5% |
| No Impact | 6 | 15% |

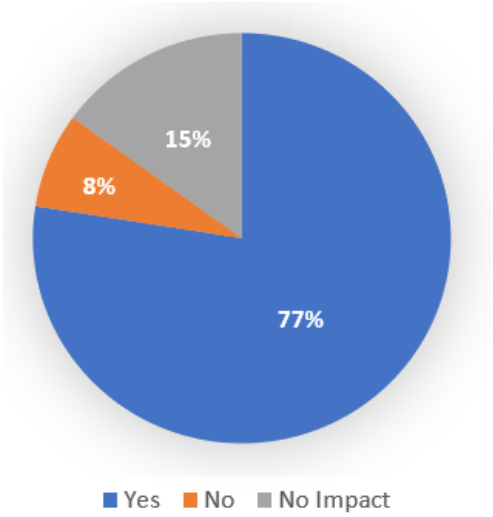


Fig. 7. Demonstrates how people from the surveyed sample size responded to whether they would want to move to a block-chain based voting system

## V. Results

### Weighted Voting Results

In this section, we would be discussing the observations from the comparative study between traditional voting and weighted voting explained in section III.

As we can see for the weighted voting results above, in section IV, using weighted voting would be a better alternative

 

*Traditional voting observations*

As can be seen from the results in table 2, using the traditional voting process, candidate A would have won, considering he had won a 'majority' of the votes (4 out of 10). This would simply mean that there were only 40% of people who would say that candidate A's views and objectives would align with theirs. Whereas, the remaining 60% of the people did not think candidate A would fulfill their demands in any way.

*Weighted fuzzy voting observations*

Compared to traditional voting, if we make use of weighted voting and check the results in table 2 above, we would see that candidate D would be the clear winner.

That would be far more acceptable to all of the people because everyone voted for candidate D in one rank or the other. This would mean that everyone felt that candidate D would be able to meet most of the demands of all of the people.

**Blockchain-based Online Voting Survey Results**

We found that 31 (77.5%) of the 40 people said that they would prefer voting using blockchain technology. 3 (7.5%) of the 40 preferred the traditional process as they still did not trust technology too much with the votes and 6 (15%) of the 40 were good with either of the two options. It would be good to point out that out of this sampling group, only 22 had gone to cast their vote in the last election, which would be a meager 55%.

## VI. Discussion

As we can see for the weighted voting results above, in section IV, using weighted voting would be a better alternative to the traditional process of being able to cast just one vote, as that helped us select a candidate who would be able to satisfy significantly more voters. This way, the voters would be happier with the process as they would know that some, if not all, of their views, are represented and more people have a voice in that representation.

This would in turn influence people, who were disillusioned into believing that voting is inconsequential as their votes would not matter, to cast their vote.

As can be seen from the statistics gathered and mentioned in section III, 77.5% of the people would like to move to the blockchain-based voting system as they are much more secure and voting can be cast from the comfort of their homes or even a few minutes' availabilities in their daily schedule. If we factor in the 15% of the sampling voters who said they would be good with either, we see that a massive 92.5% of people would be happy to see the change. This would, again, encourage more voters to cast their votes and more people can be happy with the voting process being secure, efficient and easy, with more effective representation who can cater to a wider number of people.

## VII. Challenges

Like in any other change, there are obvious issues and concerns that would need to be overcome to oversee the changes suggested in this article. As rightly pointed out in [6], the primary hurdle is the government and other agencies in power would need to ensure broadband access to all and basic digital user skills are imparted to all. The inherent complexity might also hinder the implementation and public acceptability of blockchain [11]. It wouldn't really be as simple as going to the voting station and just casting a vote, where people wouldn't really need any technology or skill of any kind.

Another issue is the quality of the software/application used to conduct the voting process. Studies have shown that, on average, the number of issues per 1000 lines of code can be somewhere between 15 and 50 [12]. People anyhow shy away from the use of technology in the domain of voting. If the product rolled out is not properly developed and tested, it may lead to bugs and issues on the voting day, which would lead to serious repercussions and people losing their trust in a modernized voting system altogether.

## VIII. Conclusion

Technology today has improved in leaps and bounds over the past two decades. It helps us in every phase and facet of our lives. The voting process used in most places across the world, on the other hand, is still very much still the legacy process that has been used for so many years. While that process is tried, tested and effective, it is not without gaping flaws and shortcomings, which are increasingly becoming a concern in the modern world. Like everything else, the voting process has to evolve and be modernized.

The novel approach explained in this article would, beyond doubt, be a step in the right direction. The combination of Fuzzy Weighted Voting along with Blockchain Technology would help people select the most effective and appropriate representative as a whole and help people cast votes securely, from the comfort of their homes and around their busy schedules, while continuing to do their civic duty and responsibility to cast a vote.

As had been mentioned before in the article, there are certain limitations to the scope and solution provided in this article. For the sake of brevity, initial user authentication was kept out of scope for this article. We have relied on the existing technologies and products in the market for this. But, they too come with shortcomings. As a future scope, we plan to introduce pattern recognition and Blockchains to tackle the authentication part of the issue.

Another shortcoming that would need to be addressed in the future would be to handle the blockchain necessary shortcomings of forking and the longest chain handling. Whenever there is a forking scenario, the longest chain of votes is considered. Research needs to be done to avoid or otherwise handle the forking scenario(s).

 

The process explained in this article if implemented in conjunction with proper resources, would resolve the much needed, but ailing, voting system. People would regain their trust in voting and the entire process would be quick, efficient and most important of all, secure and impartial.

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