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Providing Optimal Electoral Roll Architecture, Verification And Management Strategies: Evaluating The Development Of Technical Systems

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Abstract

In the development of any country, fair and transparent elections play a vital role. To order to carry out this mission, voters must be known with the greatest precision. Governments have implemented electoral roll management systems for identifying their voters, for confirming their voters, for checking duplicity, for avoiding duplicity, agreeing on the voting zone, and eventually for checking the voting zone. These all include several semi-distributed semi-central processing activities that need to be done with great precision in order to ensure the whole process for all parties and the people voting for these parties can be made transparent and equal. System designers often find it difficult to select the best algorithms, architectures and protocols to develop in order to develop such a humorous system. In this study, we evaluated the algorithms, architectures and protocols to help designers choose the best combinations possible for designing the optimum electoral roll management (ERMS) method. In addition, our analysis also recommends some additional optimisations that can be made in this field on the basis of work studies.

Keywords: *Electoral roll, management, identification, verification, duplicity, checking*

1. INTRODUCTION

Electoral roll management is a multi-disciplinary problem set, which includes the following domains,
Advanced Image processing for capturing & processing citizen's bio-metric information. High level signal processing in order to evaluate different parameters like citizen's location, profile management, etc.

Classification & prediction techniques which assist in evaluating outliers from the given datasetDuplicity detection and prevention algorithms based on recommendation and classificationMachine learning algorithms for intelligently allocating the citizen's voting booths. In order to perform these tasks, architectures and algorithms have been proposed that aim to improve the overall accuracy of the system, by adding multiple layers of verification, processing and classification at each stage of the system. These systems work in a semi-distributed-semi-central architecture. Which means that these systems do a major part of the processing centrally and some portion of computation is done in a distributed manner. For example, the enrolment of citizens, verification of citizens, etc. is usually done by a distributed entity, while checking for duplicates is done via a central governing authority. While, finally all computational results are reflected on the central processing entity, but distributed entities are still needed for micro-management of the citizen's data.

Due to the humongous complexity of this task, researchers have developed different systems that tackle each of the electoral roll management tasks individually, while a central combination layer aggregates the processed data and stores/processes it on a central entity.

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In order to evaluate the performance of these algorithms, the next section first describes some of the state-of-the-art and recent techniques for ERMS, followed by their performance comparison. This performance comparison helps researchers to further improve their own implementation based on the learnings learnt from the advances and drawbacks of the existing systems. The section is followed by some of the recommendations and optimizations that can be done in order to further improve the overall system performance.

2. LITERATURE REVIEW

Electoral roll management is a humongous task due to the following aspects,

- Citizens come from different cultural, social and economic background; therefore, each sect has a different mindset during enrolment.
- Security of the citizen data is a big concern.
- Non-repetition of data is a must to avoid duplicity during voting.
- Assignment of the citizen to their polling booths requires centralized and decentralized systems to work together.

In order to tackle these issues, researchers from various fields have mentioned different solutions for different geographies. The work done in [1] discusses an overview of all the e-voting systems over the past 15 years. They suggest dividing the areas into smaller geometries, called as hubs, and then manage these hubs at a macro-level in order to improve the efficiency of e-voting. Another issue is raised by [2] wherein, computer-based image processing for counting the ballot votes might pose a threat if the designed image processing software is buggy. This is a valid concern, but has been sorted out by extensive testing of any processing software by all parties before its use for real-ballot data. Electoral rolls can be manipulated even with the knowledge of partial data. This concern is mentioned in [3], wherein the ballot data is attacked partially in order to make sure that the manipulating party always wins. These attacks have little impact on the roll management system, but they are the research challenges that can be taken up the readers of this text.

Electoral roll management is done in order to facilitate transparent voting, and the dependency of this process on the geographical landscape is very high. Like the work done in [4], wherein Canadian e-voting system is studied, and it is concluded that a hybrid version of semi-local and global system is needed in order to ensure proper roll management solutions. This hints at the first use of ledger-based blockchain systems for roll management. A similar work is mentioned in [5], wherein state elections in the USA's Ontario are described. They mention the use of strict policies for roll management and voting in order to create a highly effective and transparent voting system. Due to dependency on technology, voting systems must place very strict security patches for an effective voting infrastructure. In order to make the voting and roll management transparent, the case study of Swiss elections can be studied from [6], wherein blockchain and AI has been proposed in order to ensure security and stability in the system. A similar work on the swiss elections is done in [7], that indicates the importance of protocols while designing electoral roll systems. It indicates that the Swiss Government had adopted strong protocols in order for the citizens to exercise their fundamental rights.

In order to ensure transparency in voting and roll management, there is a need of strong privacy settings. A zero-knowledge proof-based protocol is defined in [8], wherein Moran and Noar's methods and their extensions are used in order to ensure high level of privacy in the voting system. The scheme is based on fully homomorphic encryption, and is very effective in terms of verification. A similar work is given in [9], wherein Swiss electoral roll management is studied and it is concluded that decentralized systems must be used in order to improve the overall transparency in roll management. Work done in [10] is based on Indian context, wherein Indian elections are audited, and it is seen that Risk-Limiting Audit (RLA) is one of the most efficient method to audit the electoral roll

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data. Moreover, Voter-Verifiable Paper Audit Trails or VVPATs are the way-to-go even for large scale elections.

When it comes to electoral roll management (ERM), then civilian registration into the system plays a vital role. To this end, the work done in [11], combines some of the most interesting approaches and provides a coalition of these approaches. They suggest that it is beneficial to link civil registration and vital statistics with identity management in order to maintain sustainable development. It also suggests that multiple agencies must be involved in civil registration, this helps in verifiability of the data. Health records of individuals can be taken as a verifiability feature for the citizens. Cloud-based registration must be done in order to east the registration process for the citizens. eLearning courses must be conducted for the citizens to learn and adapt to the newer technologies. Birth registration can be extended to voter registration, and based on the immunization record of the citizen, they can be added to the electoral roll. Economic Analysis of the individuals for Civil Registration Data using Lao's principle. Obstacles in birth-based registration systems must be studied and solved. Based on these parameters, the citizen's electoral roll system can be designed. A similar kind of research is done in [12], where researchers suggest that birth-level electoral roll registration is of utmost importance, and must be taken into action effective immediately. This is proven to be true by so many developed nations, wherein the citizen's vote directly based on their passport numbers, and there is no need of any other identity for the citizens. A brief summary of these methods is described in [13], wherein the researcher lays down the foundations for roll management, verifiability, and registration in order to have a defrauded democratic election process.

A thesis [14] describes how iVote and vVote systems have proven to be effective in Australian elections, as they showcase the use of strict privacy protocols, along with single-identity management systems. This work can be used as a benchmark for result evaluation of any kind of voting system. A good read can be [15], wherein different kinds of electoral roll and vote verification systems are described. In the given work, there are communications by more than 20 authors for validating vote management systems. The book doesn't come to any conclusion about these methods, but mentions some of the state-of-the-art researches done in this field.

In order to track the genuineness of the election process, the work mentioned in [16] allows for checking the vote-bias and seat-bias in areas with citizens of different locales. They use the Jeferson–D'Hondt method in order to perform this task. This can be used for verifying the voter's voting patterns in a given voting area. A similar game theoretic approach is mentioned in [17], wherein different game theory models are proposed in order to evaluate the citizen's verifiability in a given area. Chapter 5 in the book on Election management [18] indicates the challenges in voter registration. They describe the use of distributed and central systems based on blockchain and AI in order to maintain the citizen records. This document combined with [19], can serve as a base line for development of a verifiable electoral roll management system. The CHVote System Specification mentions the number of levels which must be present in an electoral roll management system for verifiability and traceability. A study involving credibility and efficiency of digital tools in electoral roll management is done in [20], they suggest that digital tools must be used only where they have full trust values, while they must be replaced by manual systems even if there is 1% chance of trust degradation.

The first work showcasing the use of blockchain for roll management is mentioned in [21], here researchers have showcased that blockchain-based roll management can lower the security risks on the system. They have discussed the use of quadratic voting in order to improve the overall security of voting and citizen management. A series of attacks and security issues are persistent to e-voting systems. Blockchain-based methods like [21] tend to solve these issues, but one needs to study these issues before designing the roll management system. A description of these issues is given in [22]. These issues include leakages in data, hacking of ballot-counting systems, falsification of transparency during voting, etc. A small tester for these roll management and voting systems is

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mentioned in [23], wherein small polling stations can be rigged using manual interventions during voting. The system designed in [23] showcases the different test cases that can be checked in order to make sure that rigging of the electoral roll is difficult, and cannot be done easily by any of the independent parties. This work takes its inspiration from [24]. The work in [24] describes how to secure digital software systems from their core, so that there are minimal chances of data rigging in them. This involves data verifiability, trust management, decentralized checking, etc.

Data verifiability can be achieved with a carefully designed distributed ledger system. The blue print of such a system is defined in [25], wherein VMV or Verify My Vote system is described. This system allows for a decentralized ledger to take control of the genuineness of a particular citizen/vote in the system. The checking is done with the help of verifiers (a.k.a. miners), who would automatedly check for the number of valid ledger entries based on a majority algorithm. They have termed this protocol as Selene protocol, which utilizes multi-level encryption and hashing in order to secure the voting system. This system is shielded from many attacks like man-in-the-middle, DDOS, etc. Another verification model based on blockchain is mentioned in [26]. It uses the Ethereum blockchain, which internally uses smart contracts for data management. Each citizen's data is stored in the form of a contract, and this contract is linked with other contracts based on the citizen's location, age group, gender, etc. All these contracts are then percolated into a single ledger in order to create a highly effective, secure, and trust-worthy blockchain ledger. This ledger is then used for roll management, and e-voting.

An interesting but naïve approach for citizen enrolment is mentioned in [27]. Here Aadhaar card data is scanned in real-time and compared with a central identity repository to evaluate the person's credibility. But this system has large number of drawbacks, because Aadhaar cards can be compromised, moreover the government doesn't provide any kind of viewing capabilities for the citizen's data. Thus, these systems will always be prone to masquerading and spoofing attacks. In order to resolve this issue, an interesting work is proposed in [28], wherein researchers have mentioned the use of bio-medical, smart-phone and location data in order to improve the citizen tracking process. The work is done by Ecuadorian researchers, but it is applicable to any kind of system. This work can be combined with the work in [29], wherein a software architecture is defined for maintaining and securing citizen's information. This architecture also recommends the usage of blockchain-based ledger systems to store citizen data. It also proposes the use of different side-chains for voting, so that the overall system transparency can be improved. The architecture is named as EXOSOUL and it uses a 3 layered approach for solving the security and trust issues. It first defines the scope for and inferring citizen's ethical preferences, treats privacy as an ethical dimension managed through the disruptive notion of active data and finally automatically synthesizes ethical actuators, i.e., connector components that mediate the interaction between the user and the digital world to enforce the ethical preferences. The architecture of the exoskeleton can be seen from the following figure,

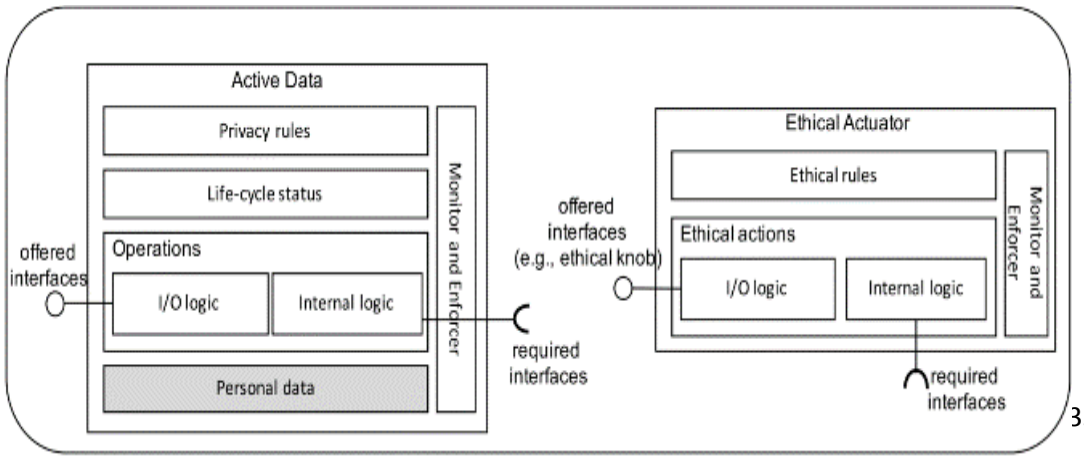

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Figure 1. Architecture for securing citizen information based on [29]

A novel work that utilizes mobile devices along with personally identifiable information is mentioned in [30]. In this work, the researchers have effectively proposed the utility of mobile devices for authentication, authorization and user tracking using mobile devices. This includes g human physiological (e.g., face, eyes, fingerprints-palm, or electrocardiogram) and behavioural features (e.g., signature, voice, gait, or keystroke). These features are investigated, and it is found that there is a need for a system that can combine the features of face, iris, finger print, voice signature, gait, keystroke functions, etc. in order to develop a highly secure and accurate system for citizen enrolment. They have mentioned that doppler radar, vocal resonance, mobile malware threats, adversarial machine learning, machine learning, and blockchain-based authentication will provide a way for the future generations of software systems to identify users with utmost ease.

Another interesting research is performed in [31], wherein researchers have proposed the addition of 'citizenship' as a question in the census. This simple addition allows for the government to check for the number of citizens that are not registered with the central authority and revoke their voting rights. Due to this simple experiment, the amount of trust-level was increased by 28%, which is a very big number when a massive population is considered. A similar work is done in [32], wherein user tracking is done based on the news articles that are spread by the user on social media websites. In this work, the researchers have tracked users based on the content shared and consumed by them on their social media handles. Based on this research, one can develop systems that are highly complex, and assist in tracking citizens based on the social profiles. This work is further extended in [33], wherein different benefits of civil registration are mentioned. This will encourage citizens to register themselves with the government, and thereby create a better system for ERM. This work also indicates the use of decentralized ledgers in order to perform the said task. Some methods to identify citizens based on their daily location patterns is indicated in [34], wherein different citizens are tracked using their number plates and location data. This helps the government to continuously track and validate the ERM systems. Certain P2P approaches are also devised for this purpose. For instance, the work in [35], boosts self-awareness in citizens, so that they can report about their daily updates to the government. By doing this, the government is able to update the data of responsible citizens, and thereby create a robust ERM system. While governments are trying their level best to maintain ERM systems, citizens also play a very important role. Thereby the smart cities initiative by the government is a crucial step towards this direction. The work mentioned in [36] utilizes smart cities in order to improve the computational intelligence of the ERM. Sensors, location devices, internet hotspots, camera-tracking, etc. facilitates the ERM system's accuracy. Here too, blockchain and AI methods come up as the front runners in handling the security and traceability issues. An extension to [36] is proposed in [37], wherein vehicle-based tracking of the users is done in order to improve the ERM systems. The work in [37] uses a combination of sensor data, and image processing in order to track the citizens and assist them in case of any critical conditions, thereby improving the citizen safety.

To further enhance the systems' security a Voter-verified paper audit trail (VVPAT) system is described in [38], that combines the power of offline voting and online voting using a distributed ledger system, which can be further extended using blockchain technology. A similar work is also performed in [39, 40], which uses formal security models and privacy preserving tools in order to facilitate the process of ERM and e-voting. Through the research performed in various contexts, [41, 42, 43, 44] can be understood in terms of using machine learning or deep learning methodologies within the framework of ERM and e-voting. Thus, we can observe that ledger-base, blockchain, AI, sensor fusion, cryptographic techniques, security protocols, user patterns, social interactions, smart-phone data and multi-media processing are the pillar stones of ERM systems. An evaluation of these techniques is done in the next section.

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3. EVALUATION OF TECHNIQUES

In this section we evaluate the different techniques for ERM, and measure their impact on the ERM systems. This evaluation is done based on the number of verifiable research algorithms mentioned for the given topic, and the number of places where the particular technique has been used. The following table indicates this evaluation,

Table 1. Impact of different techniques on ERM

Technique	Impact on ERM	Complexity	Security
Offline registration and voting	Very high	Very High	Moderate
Smartphone-based systems	Very high	High	Moderate
Ledger-based blockchain	High	Very high	High
Sensor-based systems	Low	Moderate	Moderate
Cryptographic systems	Moderate	High	High
Security rules-based systems	Moderate	High	High
AI, Blockchain, Smartphone, Social Media and Sensor systems, Security protocols	Very High	High	Very High

From the given table we can observe that the combination of AI, Blockchain, Smartphone, Social Media and Sensor systems, Security protocols is the most effective one when it comes to managing the ERM system. We would recommend researchers to work in that direction for an effective system design.

4. Conclusion

ERM frameworks require extensive design and planning when implementing in real time. It is clear from the review that offline systems are prone to attacks and therefore online systems, such as smartphone authentication, can be very good starting point for ERM, coupled with offline verification. In addition, the registration of citizens at birth level is extremely important and needs to be examined more fully. The most successful way to handle ERM systems is to merge AI, Blockchain, Mobile, Social Media, registration of birth standards, sensor systems, and security protocols. This text shows that managing an ERM is a multidisciplinary problem, and that centralized, decentralised and offline systems are to be combined. It is necessary to deal with it.

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