Michael Zipperle, Florian Gottwalt, etal. (2021) "A Machine Learning and Blockchain Platform for Operation Risk Management", Int. Conference on Future Communication (VICFCNT), VIT Chennal, Nov 2020, and also to appear Springer Lecture Notes in Electrical Engineering, 2021, [BEST PAPER AWARD].

A Machine Learning and Blockchain Platform for Operation Risk Management – An Application to Real-time Risk Awareness System Development

Michael Zipperle, Florian Gottwalt, Marius Becherer, Ke Wang, Yu Zhang, and Elizabeth Chang

University of New South Wales, Canberra, Australia
{m.zipperle, f.gottwalt, m.becherer, ke.wang9, yu.zhang, e.chang}@adfa.edu.au

Abstract. This paper presents a machine learning and blockchain platform (the Platform) for Real-time Risk Awareness, management and control for large enterprises in the area of big data analytics, the ground truth of heterogeneous information powered by AI and Blockchain. We evaluated the platform through a real-world application known as Real-time Risk Awareness System (ReRAS) to address enterprise risks, and the big data analytics and the Platform achieved 95.8% risk identification accuracy and a possibility of human effort reduction on the risk identification at 90%.

Keywords: risk management, big data, heterogenous information, machine learning, blockchain platform

1 Introduction

Big data analytics, heterogeneous information management, accountability, and security using AI and machine learning are the biggest challenges for many governments and large private enterprises [1,2]. Real-time security and risk management are the key issues and require a mandraulic human effort to investigate and time-consuming to determine the risks and achieve greater accuracy. Currently, there is no ready used real-world tools or platforms available that can be deployed or plug into the existing inter- and intra-enterprise network environment. This is mostly due to the technical difficulties in transforming the large-scale unstructured data into structured data and particularly in real-time while data are continuously changing and evolving in the real world environment [3].

In order to address the above issues and reduce the risks including big data security, single source of truth, the ground truth of transactions, data asset, and accountability for large government enterprises and or multinational corporations, we developed a practical machine learning and Blockchain technical platform that can be used and deployed in the real-world setting. We validated the platform through the development a real-time risk awareness system, coined

ReRAS, which employs AI techniques, such as text mining, machine learning, and blockchain and can handle large unstructured enterprise data in real-time, extract and perform interrogation and audits against enterprise data policies, processes and predefined business rules without human intervention. We achieve this through three steps consist of (1) text mining to extract features for (2) the document classification, and consequently (3) document-type adjusted text mining is executed. During this process, the whole transaction history of all acquisitions is tracked in a blockchain to ensure transparency, data security, and accountability. Hereby, compliance-related data for prospective compliance checks are stored on the blockchain whereas the actual evidence is stored on a distributed file system.

The structure of this paper is as follows: We conduct an overview the related work of our research in section 2. In section 3 we present the overall framework of AI and Blockchain platform and application to Real-time Risk Awareness System. In section 4 we evaluate the accuracy and the performance of the platform with ReRAS. Finally, we evaluate our platform through ReRAS in section 5, and this is followed by the conclusion of strength and future work with the platform in section 6.

2 Related Work

The automated enterprise risk identification in the area of data interrogation, auditing, and risk decision making was first presented in [4]. High-risk data and transactions should be analyzed more often than low-risk ones [5]. This leads to the requirement of using AI to carry out high-risk management not only continuously but in real-time to proactively avoid the impact of such a risk. Real-time big data and heterogeneity in types of analytics require state-of-the-art automation technologies. Large institutions like IBM have proposed to use big data analytic techniques and implemented the concept [6]. However, achieving high efficiency, accuracy, and accountability while reducing costs, time, and effort, especially in the public sector, is not available in the marketplace. The main reasons quoted for that are governance complexities, cyber is everything (data protection, cybersecurity considerations, staff training), full transparency, reporting on steroids, and skillset shortages [7]. The authors in [8,9,10] have described requirements and problems for the introduction of continuous auditing in Nigeria, Malaysia, and the UK, but no ready used AI platform, or conceptual models, or concrete implementation or evaluations in the literature to date.

A core element of continuous auditing is the use of state-of-the-art text mining and machine learning techniques to automate manual processes of traditional auditing. These techniques have developed rapidly in recent years and offer great potential for the use in continuous auditing[11].

Furthermore, blockchain technology has not only established itself in cryptocurrencies but also offers various opportunities for the use in public sectors [12]. Through key characteristics of a private blockchain, being immutability, transparency, accountability, and security, the requirements of public sectors

can be fulfilled, and thus, the introduction of continuous auditing in the public sector can be made possible. While related work in [13] have proposed a concept of how blockchain can be used for the trustful storage of machine learning data and authors in [14] have proven that blockchain can be used to track data accountability and provenance, to the best of our knowledge, there is no proposal for how blockchain can track the real-time auditing process.

In summary, continuous auditing is becoming increasingly important in the public sector, as the amount of data to be audited is growing rapidly. Only with an automated approach, public governance can be ensured in the future. To implement continuous auditing in the public sector, various challenges need to be addressed. Firstly, there is a lack of a concrete concept on how to replace the traditional auditing process with an automated continuous auditing process. Secondly, there is a lack of an approach that shows how state-of-the-art text mining and machine learning technologies can be used for process automation. Thirdly, there is a lack of an approach to how blockchain can be used to track auditing processes in real-time.

3 An AI and Blockchain Platform for ReRAS

A Machine learning and Blockchain Platform is developed in this study to automatically and timely analyzing the risks and its application to ReRAS is completed and consecutively accomplishes four tasks, including text extraction, document classification, compliance checking, and blockchain assurance.

The workflow of the Platform performing the tasks is demonstrated in Fig.1 in which each task is individually annotated. Specifically, when users upload a heterogeneous dataset following the risk policy provided by the enterprise risk division, the Platform through it application to ReRAS automatically detects and conducts text mining on both the evidences and policy to extract the information required in the following tasks. The extracted information will be stored in a document-based database, based on which the evidences are classified by learning their textual features in order to determine the compliance level of the uploading process. After updating the database with the classification, the purchase entries specified in the checking list from the auditing committee will be matched with the data extracted from the evidences for a numerical compliance audit. Combining both compliance results, a risk report is generated lastly. The heterogeneous data, transactions through risk classification are hashed and stored on the blockchain to provide a full, immutable audit trail.

4 Evaluation Design

We prototypical implemented ReRAS and evaluated it on a real-world dataset provided by the procurement audit team of a large-scale public sector. This organisation is currently suffering from the difficulties of traditional auditing methods for most of its business perspectives and endeavouring to improve this situation.

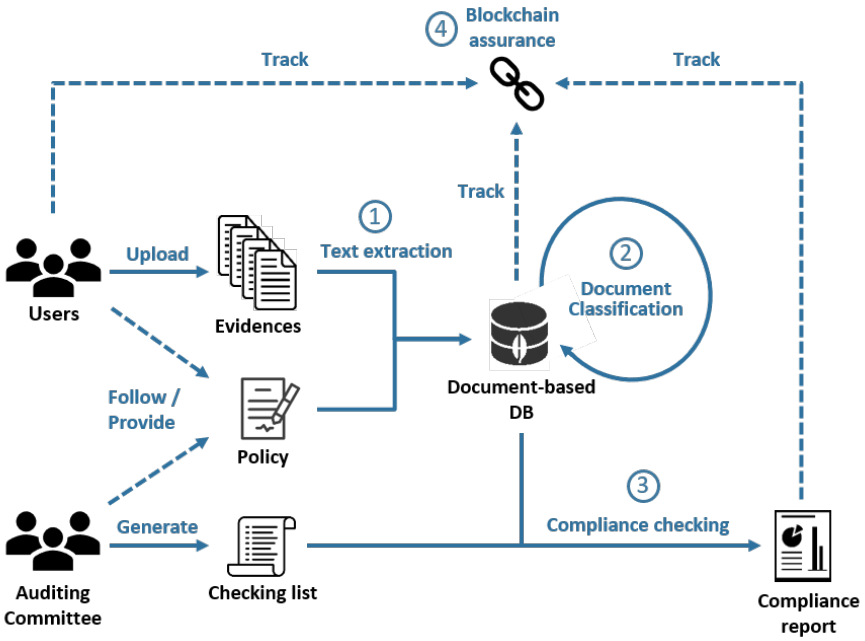

Fig. 1: ReRAS workflow

The major tasks of the auditing team include initiating annual procurement auditing process, requesting purchasing evidences from purchasing officers, comparing the unit price, quantity, total value, exchange rate, date and description from the annual financial report form (checking list) against the information in the uploaded evidences, and generating a compliance report to procurement managers. We evaluate ReRAS by automatically accomplishing all these tasks, achieving auditing accuracy higher than satisfactory, as well as completing within a short period of time.

4.1 Dataset and pre-processing

The organisation provided 660 purchasing entries and corresponding evidences for evaluation. The entries are stored in an excel sheet which contains columns of purchasing number, item name, unit price, quantity, total value, purchasing date and exchange rate. This sheet is used as the checking list in our evaluation. In addition, the evidences for these 660 purchases are packed into file folders, and each folder is titled by the corresponding purchasing number. Different evidences are included in the folders, such as purchase orders, tax invoices, customer price list, communication emails and screen captures, all of which can be considered as purchasing evidences according to the procurement policy of the organisation. Various formats of files were detected in the uploads, such as .docs, .pdf, .xlsx,

.png, .msg and .zip. Without data pre-processing, there are 1480 files in total in the evidence folders.

4.2 Baseline

The true compliance level of the 660 purchasing entries is absent, therefore we need to adopt manual approaches to the obtain the truth as baseline for evaluation. To this end, four postgraduate students were hired to manually check the purchases against the evidences and figure out the real compliance situation of these purchases. They were required to record their working hours during the manual process, as well as the details of their manual auditing results such as insufficient evidences, incorrect uploads and incorrect purchasing information.

4.3 Evaluation procedure

The evaluation mainly focuses on three perspectives including auditing accuracy, processing time and labour consumption.

Regarding evaluating the accuracy of ReRAS, we employ a classification approach to compare the auditing outcome predicted by the proposed ReRAS against the baseline. A confusion matrix is used to define the classes of the four situations, which are True Positive (TP), False Negative (FN), True Negative (TN), False Positive (FP). Accordingly, we will measure three classification rates including *Accuracy*, False Positive Rate (FPR) and False Negative Rate (FNR), where the *Accuracy* gives an overall accuracy level of the compliance checking results generated by ReRAS, while the FPR and FNR show the Type I and Type II error rates respectively in our case.

As for the processing time, we will record the time that ReRAS spends in processing and analysing the 660 purchases and the corresponding evidences. Then this processing time will be compared to the hours spent by the four postgraduate students in obtaining the baseline.

With regard to the labour consumption, we will compare the number of staff usually involved in auditing 660 purchases to that operating the system and generating a compliance report.

5 Results and Discussion

5.1 Accuracy evaluation results

The results of the accuracy evaluation are shown in Table 1 and indicate, that ReRAS is able to achieve an overall 95.8% accuracy in auditing the compliance level of the 660 purchases. It means the system has 95.8% chance to predict the same results as the true situations, which is rather promising for a practical application.

In addition, the system achieved 0.007% false positive rate, which means the system almost did not make any Type I error in the evaluation. In other

		Baseline		
		Compliance	Incompliance	
Prediction	Compliance	TP: 347	FP: 2	Precision: 99.4%
	Incompliance	FN: 26	TN: 285	FOR: 8.4%
		TPR: 92.7%	FPR: **0.7%**	Accuracy: **95.8%**
		FNR: 7.3%	TNR: 99.4%	

Table 1: Accuracy Confusion Matrix

words, the system would not miss any in-compliant purchases in the checking list. Meanwhile, this leads to almost 100% precision rate indicating that the system had full confidence in finding all the compliant purchases without mistakes.

Moreover, the true positive rate reached 92.7%, which denotes the system mistakenly predicted 26 cases as in-compliant purchases while they were in fact compliant. These 26 mistakes belong to Type II error, and they would require extra human effort input in practice to confirm their true compliance situations. To figure out the cause of the mistakes, we manually explored the evidences corresponding to the 26 purchases. It turns out that amongst the 26 mistakes, 13 cases had the pictures with so low quality that the OCR could not properly extract any valid information from them; another 10 cases had the tax invoices in which the tabled values were not well aligned inside the table cells thus leading to fault value extraction; and the last 3 cases were resulted from different round approaches being used by the auditing and purchasing officers. However, 26 out of 660 cases is acceptable according to the auditing officers of the organisation as manual checking could also make such number of errors.

5.2 Other evaluation results

In addition to accuracy evaluation, we also compared the time and labour consumption between ReRAS and traditional manual auditing approach, which are summarised alongside the results of accuracy and Type I and II error rates in Table 2.

ReRAS and the manual auditing approach are compared based on four indexes. Regarding processing time, ReRAS only took only 5 minutes to complete processing all the evidences of the 660 purchases, while 120 hours in total were spent by the four hired postgraduate students to audit the evidences. Therefore, the system substantially outperformed the manual audit in terms of processing time. In addition, ReRAS only needed one operator to run the system and another auditing officer to verify the final results, while 8 auditing officers have been in charge of this manual auditing job in the organisation costing more than 120 hours to accomplish it. In this case, ReRAS would save considerably amount of human workforce if ReRAS can be properly employed.

	Processing time	Labour consumption	Accuracy	Type I & II error rate
ReRAS	5 minutes	1 operator & 1 auditing officer	95.8%	0.007% & 7.3%
Manual audit	120 hours	8 auditing officers	≈ 90%	≈ 5% & 5%

Table 2: Comparison between ReRAS and manual audit

As for the indexes of auditing accuracy and Type I & II error rate, according to the auditing officers working for the organisation, manual auditing usually makes 10% mistakes including both type errors due to fatigue, haste, typo and other human caused fault. On the other hand, the ReRAS obtained 95.8% overall accuracy and 0.007% Type I error, which shows effectiveness and reliability of the system. Although there was 7.3% Type II error rate, these mistakenly picked purchases only cost half an hour of an auditing officer to inspect and confirm their true compliance situation, which was considered as acceptable by the organisation.

5.3 The Platform as a tool for Risk Management

The outstanding gains in the efficiency of the proposed continuous compliance auditing system have shown the great potential to reduce the workload of public servants. While this paper has addressed the particular risk of purchasing, there are many more risks in the asset and procurement life cycle which can be addressed with the proposed system. For future work, we are going to implement the auditing policies in a smart contract. This will allow a more transparent view of the policies for all entities involved in the auditing process. Further, we plan to extend our system to not only consider the purchasing risk but also other risks that occur in the entire asset lifecycle of public sectors.

6 Conclusion

Financial audits and risk management are becoming an increasingly important task in public sectors. Massive volumes of hard-copied evidence need to be audited regularly to ensure public funds are spent responsibility according to policies and regulations. Without an automated system to check between computer records and physical (paper-based) records in large-scale organization, leading inaccuracy in financial data management and human effort in managing both computer and physical records. This is one of root causes to the enterprise risk, including poor asset management, poor productivity, and poor capability of operations. To address this problem, in this paper we have proposed Real-time Risk Awareness System (ReRAS), a system which enables continuous real-time

risk management through continuous compliance auditing. The propsoed ReRAS demonstrates an auditing accuracy of 95.8% and save potential 90% human effort in auditing between the computer records and physical records.

References

1. A. Bhimani, L. Willcocks, Digitisation,'big data'and the transformation of accounting information, Accounting and Business Research 44 (4) (2014) 469–490.
2. J. Dimyadi, R. Amor, Automating conventional compliance audit processes, in: IFIP International Conference on Product Lifecycle Management, Springer, 2017, pp. 324–334.
3. P. E. Byrnes, A. Al-Awadhi, B. Gullvist, H. Brown-Liburd, R. Teeter, J. D. Warren Jr, M. Vasarhelyi, Evolution of auditing: From the traditional approach to the future audit, Continuous auditing: Theory and application (2018) 285–297.
4. S. M. Groomer, U. S. Murthy, Continuous auditing of database accounting systems using embedded audit modules, Journal of Information Systems 3 (1) (1989) 53–69.
5. D. Y. Chan, M. A. Vasarhelyi, Innovation and practice of continuous auditing, International Journal of Accounting Information Systems 12 (2) (2011) 152–160.
6. J. Zhang, X. Yang, D. Appelbaum, Toward Effective Big Data Analysis in Continuous Auditing, Accounting Horizons 29 (2) (2015) 469–476. doi:10.2308/acch-51070.
7. T. Antipova, Digital Public Sector Auditing: a look into the future, Calitatea 20 (S1) (2019) 441.
8. J. O. Orumwense, Implementation of Continuous Auditing for the Public Sector in Nigeria, Journal of Accounting, Business and Finance Research 1 (1) (2017) 19–23.
9. R. Othman, N. A. Aris, A. Mardziyah, N. Zainan, N. M. Amin, Fraud detection and prevention methods in the Malaysian public sector: Accountants' and internal auditors' perceptions, Procedia Economics and Finance 28 (2015) 59–67.
10. K. Omoteso, A. Patel, P. Scott, An investigation into the application of continuous online auditing in the UK, The International Journal of Digital Accounting Research 8 (14) (2008) 23–44.
11. R. Elshawi, M. Maher, S. Sakr, Automated machine learning: State-of-the-art and open challenges, arXiv preprint arXiv:1906.02287 (2019).
12. S. Ølnes, J. Ubacht, M. Janssen, Blockchain in government: Benefits and implications of distributed ledger technology for information sharing, Government Information Quarterly 34 (3) (2017) 355 – 364. doi:https://doi.org/10.1016/j.giq.2017.09.007.
13. T. Wang, A unified analytical framework for trustable machine learning and automation running with blockchain, in: 2018 IEEE International Conference on Big Data (Big Data), IEEE, 2018, pp. 4974–4983.
14. R. Neisse, G. Steri, I. Nai-Fovino, A blockchain-based approach for data accountability and provenance tracking, in: Proceedings of the 12th International Conference on Availability, Reliability and Security, 2017, pp. 1–10.