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Original scientific paper

IMPLEMENTATION AND PERFORMANCE ANALYSIS OF A PRACTICAL SYSTEM FOR DIPLOMA VERIFICATION BASED ON BLOCKCHAIN AND ARTIFICIAL INTELLIGENCE TECHNOLOGIES

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Abstract

The development of artificial intelligence in combination with blockchain features is marking a technological revolution in terms of the creation of different intelligent robots, and softbots, and more and more attempts are being made to create an artificial human who will be able to help, understand both the speech and the feelings of the real man. Regarding the implementation of decentralized artificial intelligence in institutions of higher education, there are delays in the implementation of blockchain systems for managing large and variable data. This is mainly due to some unique characteristics of the blockchain, which limit the possibility of data variability, and their updating in real-time. However, we are witnessing the implementation of intelligent softbots that are helping students in various fields. The purpose of creating intelligent robots, and in particular decentralized artificial intelligence, is not to replace humans, but to use human intelligence to create intelligent devices that, above all, will facilitate their lives and way of working. Through the paper, we will try to describe the synergy of cooperation between blockchain technology and artificial intelligence in the creation of decentralized big data management systems. We will give the greatest importance to the implementation of blockchain technology in the verification of diplomas, as very important documents that are generated by the institutions of higher education. We will give examples of the execution of the smart contract for the verification of diplomas, as well as the implementation of AI agents within the blockchain workspace that help in the testing and optimization of the smart contract. Through predictive techniques, and multiple regression, we describe an analysis of the verification of diplomas for a higher education institution within a year, taking simulations as examples.

Keywords: decentralized artificial intelligence, blockchain technology, diploma verification, intelligent devices.

1. Introduction

The implementation of artificial intelligence (AI) and blockchain technology (BT) in systems for the generation and verification of diplomas enables the digitization of many services of higher education institutions (HEI), but above all the prevention of misuse, the preservation of identity, privacy, the decentralization of services and their automation. AI through contemporary techniques tries by all means to digitize all the services offered by different systems, including blockchain ones, but among the biggest achievements, we can mention that there are attempts to create intelligent machines that manage to process natural human speech and at the same time to communicate with people about different problems. Today we have intelligent robots with which people talk about various problems, and seek help for problems they encounter in everyday life, including students, who have many intelligent machines that they use to learn during their studies (Tyagi *et al*,2020). BT and AI are among the technologies that are seen as the hope of technological revolutions in every sphere of life, including education. Despite the efforts to digitize many services, there are still various misuse in higher education institutions. Students need to have someone who helps them, listens to them when they have problems, and gives them instructions on how to act in their most difficult cases. AI tends to create intelligent robots, which will emit the artificial human, having the possibility that apart from speaking, they will

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also be able to understand feelings and emotional states, and offer help in different cases that arise spontaneously. And BT guarantees that all data will be private, secure, providing reliability and credibility for the services offered (Rajagukguk *et al*, 2023).

In light of the literature review's findings, we have noticed that there is initially a lack of literature on the implementation of AI in HEI, just as we found earlier about a lack of implementation of blockchain in HEI. This lack of practical implementation of these two technologies makes their integration towards practical implementation difficult. The integration of BT and AI in the generation and verification of academic credentials affects the automatic generation of services, more efficient methods of user identification, privacy protection, easier detection of possible abuses, and even the creation of hybrid models using secure data encryption and decryption mechanisms (Rustemi *et al*, 2023).

Figure 1 presents one of the main characteristics of the synergy between blockchain and AI in higher education institutions, especially for the generation and verification of academic documents. The synergy of blockchain and AI affects many processes in higher education institutions, including automatic generation and verification of academic documents, especially diplomas; privacy protection and intelligent methods of user identification in the system; detection of possible misuses, or warning against various cyber-attacks; use of cryptographic models and consensus mechanisms that contain the interconnection of blockchain and AI; scalability and adaptability of the system, decentralization and collaboration of AI and blockchain in making system decisions for events that occur spontaneously in the system (Charles *et al*, 2023).

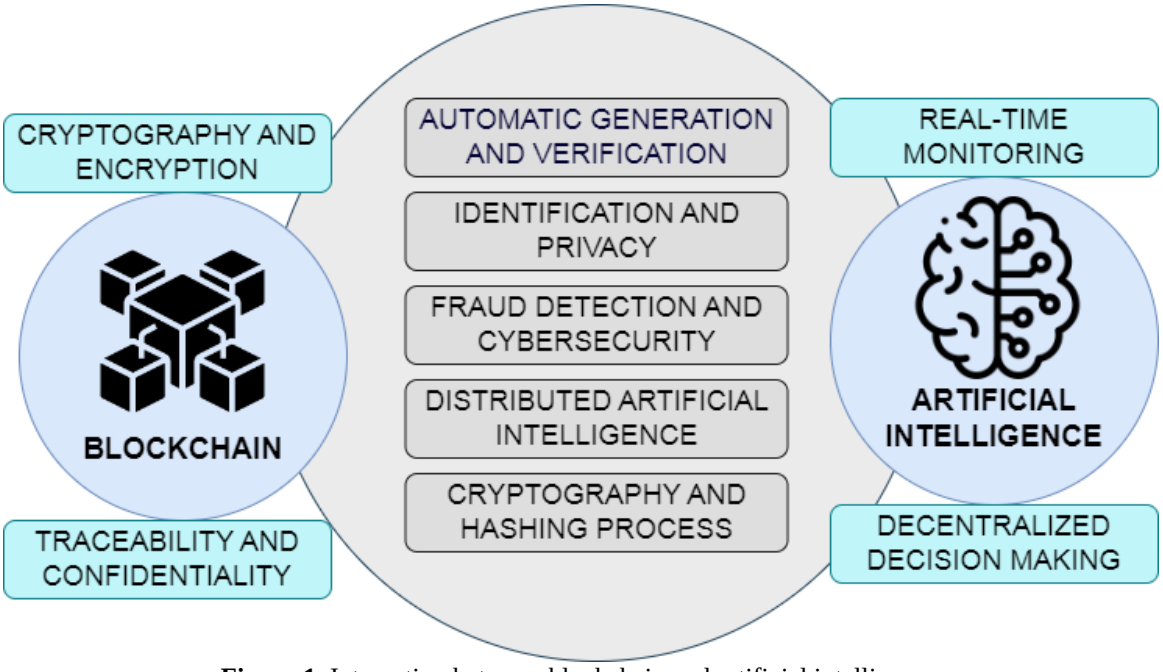

Figure 1. Integration between blockchain and artificial intelligence

BT enables all nodes that are within the network to be in direct contact for any eventual changes that may be made to their data. This means that if one of the nodes changes its data, the same must be verified by the other nodes, otherwise those changes will not be accepted. This is related to the immutability of the data and the transparency of the services of all the nodes that are part of the blockchain network. Blockchain principles according to (Ural *et al*, 2023), can be classified into: distributed ledger for all participants in blockchain networks, immutability of data without confirmation from all nodes, consensus mechanisms and cryptographic algorithms for encryption and decryption of data, transparency of services, irreversibility or regeneration of data.

2. Related Work

The generation and verification of diplomas have many advantages compared to centralized systems, however, there are also limitations that are being attempted to be overcome and blockchain to find full application in higher education institutions. Table 1 presents the advantages and disadvantages of the application of blockchain systems in HEIs.

Table 1. Blockchain system properties

ADVANTAGES	DISADVANTAGES
Privacy, transparency, traceability, identity	Lack of self-identification mechanisms, the target of numerous attacks, the cause of transparency (Cernian et al, 2021)
Reuse and adaptability, decentralization and distributed ledger	Reuse depends on standardization, adaptation is difficult especially from centralized to decentralized systems, decentralization has more deficiencies in storage for a longer period of time and response in real time. (Pandey et al, 2022)
Immutability of smart contract and blockchain platform	Every error requires the regeneration of the smart contract, smart contracts are only compatible with the Ethereum platform, which limits it in many features (Zhu et al, 2020; Kaur et al, 2022)
Safety and cost, electricity consumption, maintenance	The generation and verification of diplomas have a low cost, but their maintenance for a longer time is expensive, because blockchain itself is an expensive technology (Kaur et al, 2022; Ge et al, 2023)
Decentralized data storage, off-chain storage	All current systems work with centralized databases, and adaptation to decentralized databases is very difficult. (Wang et al, 2023)
User interface, compatibility, guide and documentation	The design of the system must be compatible for all intelligent devices, lack of documentation and experts in this field. (Abbas et al, 2023)
Fast generation, verification, online support all the time	It requires high costs, because it is in direct proportion to the energy consumed and the blockchain auxiliary equipment used for the system. There is a lack of programmers and experts in this direction (Kaur et al, 2022; Ge et al, 2023; Abbas et al, 2023)

AI helps in promoting the concept of industrialized education in intelligent education, reconstructing the learning process in higher education institutions, up to the creation of intelligent teachers who will create a new structure of the educational process, including the cultivation of students and professors with the intelligent age that dominates today (Hu *et al*, 2022).

There are some practical solutions regarding the implementation of the blockchain solution, for the generation and especially the verification of academic credentials, although some are only in the design and implementation phase of the prototype. (Averin *et al*, 2020), has proposed a model for evaluating student performance based on blockchain technology, which can also be adapted to the generation and verification of diplomas. The encryption and decryption of data is done through the SHA-256 algorithm.

Knowing the fact that in the blockchain it is difficult to revoke the diplomas after they are stored with the hash of the unique value, (Vidal *et al*, 2020), have proposed a model with blockchain mechanisms on how to revoke diplomas that are inserted with errors, which is difficult to hide from the blockchain network.

Revocation as a process can only be done using a smart contract for revocation, or total deletion of the diploma in blockchain storage, although such a solution is partial because the same diploma must be generated with a different hash value, which makes further verification difficult.

A very efficient platform for generating and verifying diplomas is the Verde platform (Nousias *et al*, 2022), which is mainly based on the creation of Verde tokens, based on ERC-20 tokens, which is based on the Business Process Model & Notation (BPMN) model. The platform is based on the tokenization of loans through Verde tokens and their storage in blockchain storage.
A practical solution of a blockchain system for the verification of diplomas based on the blockchain consortium has also been offered by (Hsu et al 2022), which, in addition to verification, has also given importance to facial recognition, to verify that the diploma that is generated belongs to the person respectively, and not to receive diplomas from other fraudulent persons.
A blockchain platform for generating and verifying degrees, which is coherent, is Cerberus (Tariq *et al*, 2023). Platform based on Ethereum blockchain, using an on-chain smart contract, and not requiring additional methods for user identification. Great importance is given to privacy, transparency of services, and prevention of fake credentials. BCert is another platform for diploma verification, which is based on the Ethereum platform using smart contracts and Interplanetary file storage (IPFS) for storage (Leka *et al*, 2022). The platform has been tested online with some 500 certificates for verification and has shown good results. EduCrypto is another system based on the Ethereum blockchain and IPFS for storage, and authentication of educational documents as well as simplification of the entire process of evaluation and generation of results. It has shown good results during practical implementation, and it mainly consists of three main modules: Admission; Examination, and Results; Third-Party Modules (Badlani *et al*, 2022).
Many other platforms have been created, different blockchain solutions that have to do with the generation and verification of diplomas, however, most of them are created on the Ethereum platform, using smart contracts, because they offer an environment with easy and many possibilities for testing before execution. It is evident that contrary to many blockchain solutions, there is still no platform that has shown long-term results in terms of the generation and verification of diplomas. There are many challenges and difficulties, however, some of the most important ones are that smart contracts themselves have their limitations, diplomas are not cryptocurrencies, difficult transfer of diplomas from current systems to blockchain systems, lack of a blockchain database for long-term storage as well as many reasons others (Rustemi *et al*,2023).

3. Diploma verification smart contract through blockchain system

The verification of diplomas is a process closely related to the insertion and generation of diplomas. All the data that is inserted into the blockchain, the same can be verified using the blockchain and AI methods which can automatically verify the document. The verification can be done based on the permits given by the administrator, a certain company that enters into certain agreements with public and private universities for the verification of diplomas. The administrator can withdraw the permits of the verifier if he suspects any possible misuse and the same one cannot verify diplomas. The verification of diplomas is very important to be carried out in the shortest possible time, however, such a thing is in direct proportion to the costs.
During the verification, the transaction must be carried out based on the predefined parameters and the payment must be made through the blockchain wallet. The verification depends mainly on the search in the blockchain database, if the diploma has not been changed since the moment of insertion in the database, which means that it has hashed the generated value from the beginning, then it will be successful. If you have made changes to the diploma, then the hash value will be different from the initial one and the verification will not be successful. Figure 2 presents a brief description of the diploma verification process through the blockchain system.

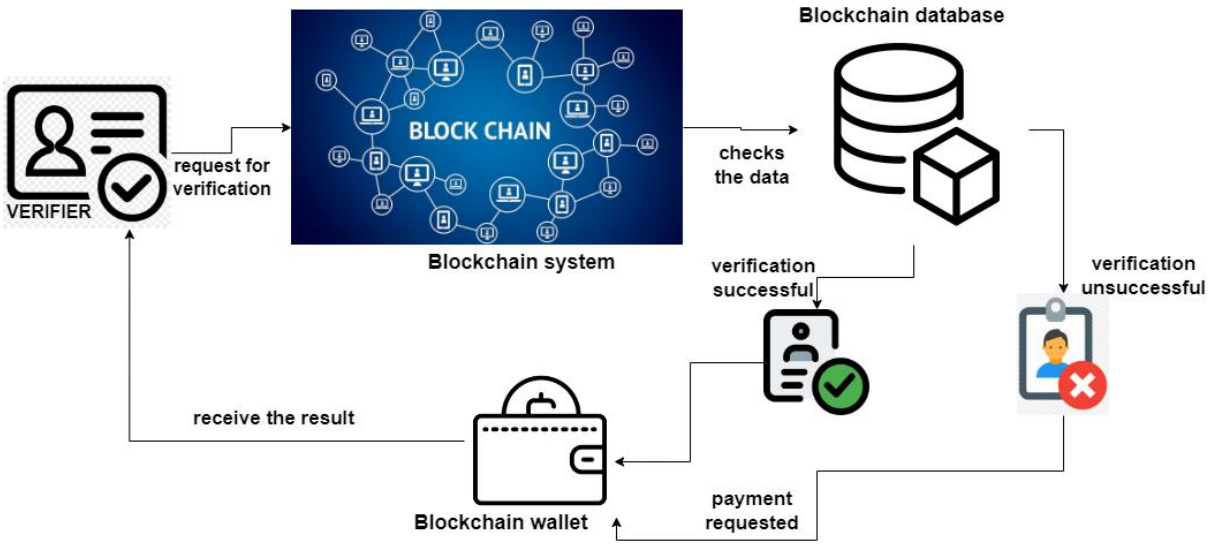

Figure 2. Verification process through blockchain system

First, to have the diploma verified, it is necessary to insert the data, which is also done through smart contact *Diploma_registration*. Then the mapping of diplomas stored in IPFS or other blockchain storage is done, as well as the loading of diplomas from the public ledger. Using a special function for storing new diplomas, diplomas are created, stored, and issued from blockchain storage. And finally, we have the function for verification, respectively the function inside the smart contract, which returns the result valid or not, if the diploma is stored inside the blockchain storage, which is searched for by hashing its unique value. It is very important to note that within the blockchain storage, after the diploma is stored, no changes can be made because any change or regeneration of the same will not have the unique hash value that it had at the beginning. Every realization of transactions on the Ethereum platform is transparent, and the same can be verified in Etherscan, which is dedicated to Ethereum transactions. It even offers the possibility of verifying smart contracts that are executed on the Ethereum platform. RemixIDE is an Ethereum Integrated Development Environment, which enables smart contracts to be tested, compiled, and deployed, even before they are executed in the blockchain network, to optimize them and allow them where necessary. RemixIDe even has integrated intelligent agents, which show you in an intelligent form, where you have errors within the smart contract and how to allow the same in a better form, to optimize the code as much as possible.

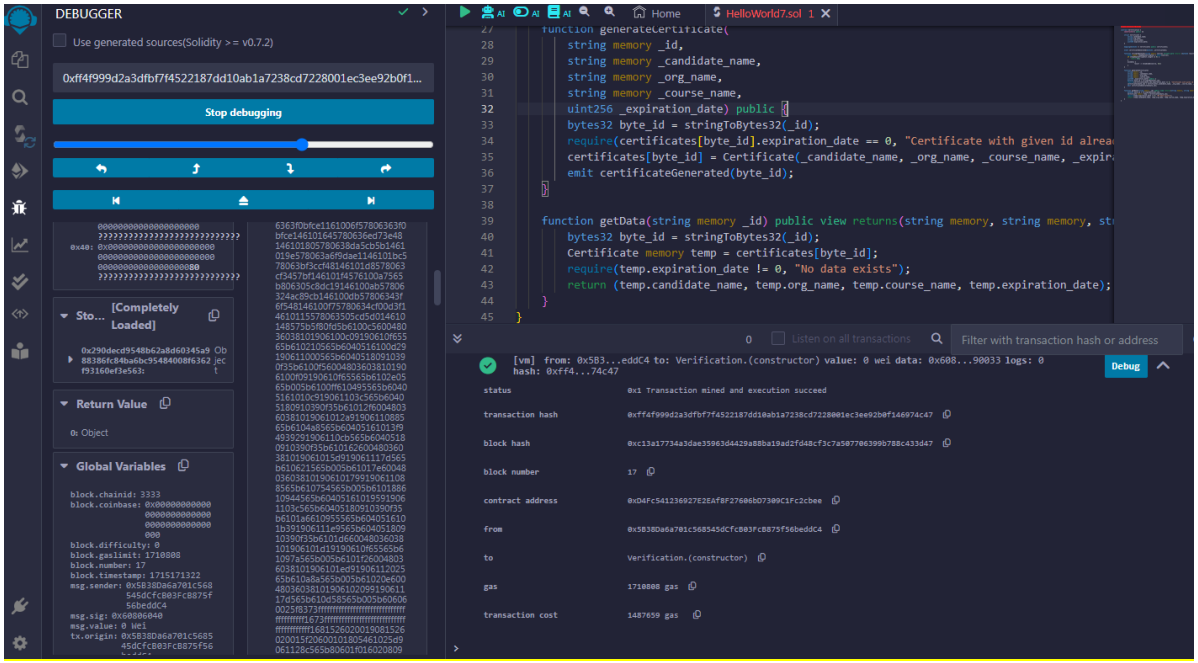

Figure 3. Execution of smart contract for generation and verification of diplomas

Figure 3 gives an example of the smart contract deployment process for diploma verification, showing exactly the necessary costs, code optimization, testing, and all the other help that RemixIDE offers to blockchain developers.

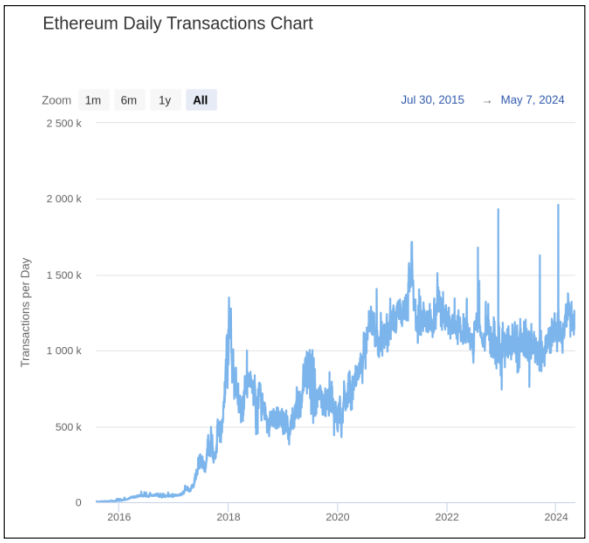

Figure 4.a. Ethereum daily transaction chart
Source: etherscan.io

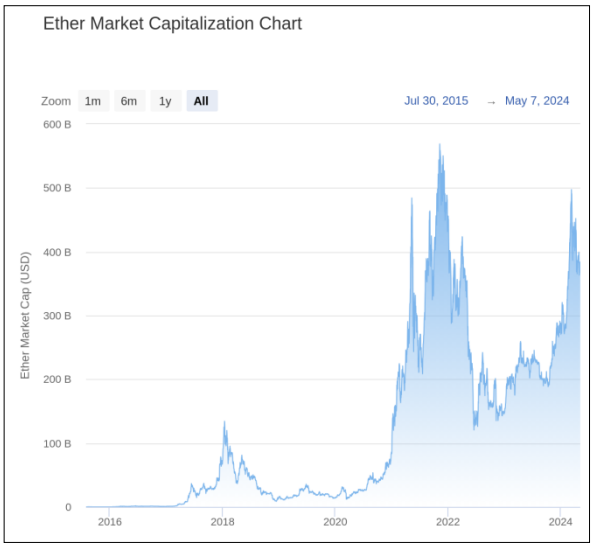

Figure 4.b. Ether market capitalization chart
Source: etherscan.io

Figure 4.a. and 4.b. graphically show the development of ethereum daily transaction and ether market capitalization. From the official data, it appears that since the beginning of 2024, the number of transactions executed in a day on the Ethereum platform is over 1 million, and it is increasing more and more. Ethereum Market Cap is at a current level of 374.85B, while the average price of ether is over 3,000 dollars.

4. Multiple Regression Predictive Analyses for diploma verification

Linear regression is a model that can predict the work in machine learning. Through this method, it is attempted to get as close as possible and as accurately as possible to a certain value that will happen in the future. Regression techniques can be used to predict and analyze the performance of the blockchain system to analyze the performance of the system at certain time intervals. The regression technique can be used for predictive analysis, system anomaly detection, resource allocation, risk assessment, system performance optimization, market analysis, etc. Calculate the costs of diploma verification, it depends on the cost of gas, the cost of deployment of smart contracts, and the cost of transactions. Although predictive techniques are techniques that depend on many factors, nevertheless the mathematical calculations that use these techniques have managed to predict the results, and most of them have turned out to be correct, thus increasing the reliability to 95%. However, for these analyses to be more accurate, the input variables should be closer to the real ones. Although there are many forecasting techniques, three main categories can be distinguished: predictive, descriptive, and decision models. The classification mainly has to do with the influence of external factors in the approach to the variables taken as a basis for the analysis (Halili *et al*, 2016). Through the work and multiple regression techniques, we will try to show some statistics related to the verification of diplomas within a year, in a higher education institution. Initially, we assume that the institution of higher education has 4 faculties within it, and for each month they generate a certain number of requests for verification of diplomas, which you have in a more detailed form in Table 2.
The equation that allows us to calculate the regression is $Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p + \varepsilon$, where ε is an ordinal variable equal to zero and σ standard deviation whose value we do not know. We also do not know the values of the variables $\beta_0, \beta_1, \beta_2, ...\beta_p$. All these *(p+2)* unknown variables must be calculated, from the variables for which we have concrete values. The data consists of n rows that we call cases, which give us values like $y_i, x_{i1}, x_{i2}, ..., x_{ip}; i = 1,2,....., n$. The estimates for the β coefficients are computed so as to minimize the sum of squares of differences between the fitted (predicted) values at the observed values in the data.
The calculation of the cost of Ethereum depends on several factors, which we have taken as examples of the data below:

Gas price: 50 Gwei (0.00000005 ETH)
Gas limit per verification transaction: 200,000 gas units
Smart contract deployment fee: 0.1 ETH

Table 2. Ethereum cost for verification diploma for one year (simulated data)

Month	Ethereum costs	Faculty 1	Faculty 2	Faculty 3	Faculty 4
1	3.38 ETH	151	55	77	45
2	2.73 ETH	142	25	75	21
3	3.79 ETH	145	121	58	45
4	4.07 ETH	254	115	14	14
5	4.81 ETH	255	114	25	77
6	5.27 ETH	254	109	65	89
7	5.28 ETH	266	152	44	56
8	6.18 ETH	255	177	121	55
9	6.04 ETH	215	200	154	25
10	5.63 ETH	159	201	148	45
11	10.06 ETH	455	265	254	22
12	6.49 ETH	155	222	250	12

Based on the data in table 2, and using available software for multiple regression calculations, without wanting to waste time in the detailed elaboration of all mathematical equations, the following tables are the regression results.

Table 3. Multiple regression techniques for verification diplomas (data from Table 2)

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	1
Standard Error	3.05965E-16
Observations	12

	df	***SS***	***MS***	***F***	***Significance F***
Regression	4	39.82889167	9.957222917	1.06364E+32	2.5708E-111
Residual	7	6.55303E-31	9.36147E-32		
Total	11	39.82889167			

	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	0.1	3.32429E-16	3.00816E+14	1.1849E-99	0.1	0.1	0.1	0.1
Faculty 1	0.01	1.26123E-18	7.92875E+15	1.3407E-109	0.01	0.01	0.01	0.01
Faculty 2	0.01	2.43781E-18	4.10204E+15	1.3514E-107	0.01	0.01	0.01	0.01
Faculty 3	0.01	2.07142E-18	4.82759E+15	4.3218E-108	0.01	0.01	0.01	0.01
Faculty 4	0.01	4.41264E-18	2.26622E+15	8.6032E-106	0.01	0.01	0.01	0.01

5. Conclusion

The implementation of blockchain systems and artificial intelligence in the educational process in institutions of higher education affects the increase in quality, efficiency, and above all current knowledge is tested and affects the acquisition of new knowledge. The synergy of these two technologies in the educational process would enable the creation of a decentralized system with intelligent features, which, apart from helping students, would also manage the process of generating and verifying diplomas, in an intelligent, safe, transparent, and decentralized way. There would be no possibility for possible misuse by any actor included in the system since everything would be managed by the blockchain, while decryption of the blockchain is almost impossible. Through the paper, we tried to once again describe the main characteristics of blockchain technology, dividing them into advantages and disadvantages for application in a diploma verification system. Then, we have given great importance to the synergy between these two technologies, describing some implementation techniques as a result of the cooperation between these two technologies. Verification of diplomas is a very important process, with which it is checked whether a generated diploma is original or not. To make such a process as accurate as possible, only blockchain systems guarantee such a thing. We have described both graphically and theoretically how the verification of diplomas can be realized through the blockchain system. We presented an example of smart contract execution, using RemixIDE, as well as official data from Etherscan.io, which shows all transactions executed in the blockchain network, and their linear growth. At the end, using predictive techniques, and

multiple regression, we analyzed how much the annual expenses of a university would be, taking as an example the simulation data, which would be part of an HEI, for the verification of diplomas.

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