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Research Article

Bridging Law and Machine Learning: A Cybersecure Model for Classifying Digital Real Estate Contracts in the Metaverse

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ABSTRACT

The metaverse indicates an ever-evolving digital ecosystem where virtual real estate has now become an asset class. These properties, subject to smart contracts on the blockchain and represent as non-fungible tokens (NFTs), gives rise to new legal and cyber issues due to the decentralized and dematerialized nature of these digital assets .This paper proposes a machine learning approach to classify the digital real estate contracts into Ownership and Lease contracts. The study utilizes a dataset of one thousand digital real estate contracts collected from platforms such as Decentraland and The Sandbox. The dataset also included attributes such as plot size, plot location, transaction value, and contract duration. Preprocessing of data included encoding categorical data, standardization of numerical variables, and UTF-8 encoded text to preserve data quality. Two classification models were used: Logistic Regression and Random Forest. The model's evaluation used accuracy, precision, recall, and F1-score as evaluation criteria. The Random Forest outperformed with a perfect classification score showing that it may have been better suited to dealing with the complexity and dimensionality of the dataset. The outcomes of the study highlight the role AI could play in automating the analysis of contracts, at the same time highlighting that cybersecurity practices are important when working with data. The framework of this study seeks to support the development of a regulatory regime and add further transparency to real estate contracts in the metaverse - as a scalable tool for future digital real estate management.

1. INTRODUCTION

The accelerating pace of digital transformation has, undoubtedly, altered legal, social systems and economical landscapes across the globe [1], [2]. One of the most disruptive innovations leading this transformation is the emergence of the metaverse [3], [4]: an incredibly broad, decentralized, and immersive digital space based on converging technologies like blockchain [5], artificial intelligence (AI) [6] [7], virtual reality (VR) [8], and augmented reality (AR) [9]. In this emerging ecosystem, digital real estate emerged as an innovative asset class [10]. Digital real estate is fundamentally different than traditional property assets, in that they exist only in non-physical form, represented as a non-fungible token (NFT) with a unique identity registered on blockchain networks and readily utilized in a commercial, recreational, or educational context on platforms such as Decentraland, The Sandbox and Matrix World [11], [12].
Digital real estate brings opportunities and complications. For example, in respect of traditional property, agreements reflect the expertise of various intermediaries, such as brokers, conveyancers and legal advisers [13]. Transactions in digital real estate will increasingly rely on smart contracts. A smart contract is a self-executing contract in which the terms of the agreement or contract are written as lines of code, which automate the transaction of property [14]. Transactions will rely on complex agreements and also introduce a new range of legal and cybersecurity risks [15] [16]. For instance, important challenges will emerge regarding validity of unilateral agreements, verification of digital ownership, immutability of the code embedded in the contract, and the jurisdiction to which the contract is subject if the agreement leads to commercial dispute [17] [18]. The merged waves of decentralised and borderless design principles of metaverse platforms may also challenge existing property law frameworks, resulting in unique challenges regarding dispute resolution, regulatory

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authority, enforceability, assessments of ownership, and most fundamentally accounts for intangible digital ownership [19], [20].

Despite the uncertainties in law, the economic opportunity for digital real estate is significant. Many emerging digital economies are beginning to mirror the behaviours of real-world investment [21]. However, with these opportunities, there are also risks to be considered related to exploitation, data breaches and cyber-enabled economic crime, all of which emphasise the need for secured, transparent, and legally aware solutions [22], [23].

This research proposes a machine learning (ML) framework to classify metaverse real estate contracts into ownership and lease contracts in the digital context. Research will utilise a curated dataset obtained through a variety of metaverse real estate platforms to research the capabilities of AI technologies with respect to enhance legal transparency[72], to help automate classification activities, manage the risks of fraud in contract, and outlines the dimensions of types of digital property agreements.

This study utilized and assessed two ML classification models which were Logistic Regression (LR) as a baseline, and Random Forest (RF) identifying the advantage of having a model that could account for non-linearities and complex interactions among the features. There were four operational performance measures used in the assessment: accuracy, precision, recall, and F1-score. Both models illustrated suitable performance, with the Random Forest classifier representing an effective, robust model for classifying contract types in the metaverse with perfect scores across all performance metrics.

In addition, the study will focus on cybersecurity in the data preprocessing stage where UTF-8 character encoding implementation took proper attention[73]. This represents an important cybersecurity measure with respect to preventing data corruption, preventing an injection vulnerability, preventing misinterpretation of metadata, and most importantly with user-generated content or content generated on the blockchain. Encoding standards in the machine learning pipeline in similar fields of practice are often overlooked. Therefore, this discovery highlights a useful cybersecurity hygiene protocol when dealing with fiat or blockchain contract data.

Furthermore, this research moves beyond mere technical implementation to account for the convergence of technological advancements and legal regulation. As institutions, businesses, and individuals continue to move toward the metaverse, AI tools serve to support real-time verification of contracts, real-time detection of anomalies, and monitoring compliance with regulations in flux. As machine learning, legal informatics, and cybersecurity combine in this way, this marks a significant point in the development of secure, smart, and regulatory-ready digital economies.

Major Contributions of the Research

- Illuminates a growing interface of legal regimes and platform governance in an emerging field of virtual property rights.
- Demonstrates the efficacy of ML algorithms, specifically Random Forest, in the classification of metaverse real estate contracts with previously unheard-of level of accuracy.
- Illustrates the significance of cybersecurity, particularly with encoding practices, as a step that occurs in the preprocessing of legal contracts.

2. AI, METAVERSE AND DIGITAL REAL ESTATE: AN OVERVIEW

The convergence of artificial intelligence, the metaverse and digital real estate represents a paradigm shift affecting various sectors of modern society and the digital economy [24], [25]. The metaverse, which is considered to be the next evolution of the internet, is created to be an immersive experience that combines features of the physical and digital spaces and creates new opportunities for engagement, commerce and entertainment [26]. The metaverse follows technologies coming together, that include extended reality, artificial intelligence, and blockchain, to build self-adapting virtual worlds where people can do many things that they do in the physical space [27]. Underlying the creation of a metaverse is continued research into hardware and software that significantly improves graphics processing to map detailed 3D environments [28]. Automated, semantic communication, combined with AI-generated content, allows for higher levels of immersion and can allow participants in the metaverse more engaging and meaningful interactions within these spaces [29]. The metaverse in not simply a technological emergence or advance but a socio-economic evolution that was pushed into the limelight by recent global events, much if not most, of which required remote work and dramatic social distancing increasing activity happening on remote platforms, foreshadowing the metaverse as a possible cornerstone of the future [30]. With digital real estate in the metaverse, there are new ideas surrounding digital and blockchain property investment; and as these assets grow in value, they reflect growing interest in virtual economies and emergent digital asset management [31].

2.1. The Role of AI in the Metaverse

Artificial intelligence plays a foundational role in creating the metaverse where user experiences and environments can not only be generated just-in-time but can respond dynamically and be automated [32]. With specialized algorithms, artificial intelligence can assist in the creation of personalized avatars where individuals can practice their identities in a unique way in the virtual world [33]. Users may never have the same avatar again while they traverse multiple worlds in the metaverse, involving economic exchanges, and experiencing digital environments through physical infrastructures and the incentives that the metaverse offers. AI's potential to generate its own content is critical for filling the metaverse with varied and meaningful objects, from virtual land to interactive Non-Player Characters [34].

AI is vital to the metaverse by helping fill it with dynamic content, create personalized user experiences, and manage operations dynamically [30]. AI is also impactful in creating realistic avatars, simulating natural language processing for smooth communication, and reshaping the virtual world to meet the preferences of individual users, which are all major efforts to keep a user engaged and satisfied in their virtual experience in the metaverse [35] [36]. At the same time, AI can take our ever-growing analytic- big-data approaches, while building virtual environments to be interactive and adapt immediately to user decisions, while continuing to give the users a sense of presence and ultimately immersion in everything there's a thing to engage with in the metaverse [37]. More recently, AI has enabled the production of realistic simulations around users and will help them engage virtually but in ways similar to their own real-world behaviors. For example, virtual assistants driven by AI, can improve their precision when giving an individual personalized guidance around the simultaneous engagement to multiple learning styles with an AI-enhanced education, and simulations and training driven by artificial intelligence can help the user engage in realistic presentations. AI-inspired and driven interactions cover a diverse range of realities in the virtual setting contributing to education specifically for creating virtual settings for students to collaborate with others on team projects [32]. AI is essential for assessing and monitoring behaviors and preferences of users, which leads to creating personalized experiences and increases user engagement and satisfaction [38].

2.2. Digital Real Estate in the Metaverse

Digital real estate comprising virtual land and assets located in the metaverse is an emerging and important investment and development area, and it represents a serious transformation of the traditional model of the real estate market while possessing its own uniquely identifiable characteristics and opportunities [39], [40]. Digital real estate with the concept of owning virtual land looks and feels similar to owning property in the physical marketplace provides people and organizations invested in a metaverse location to build and develop virtual properties and commerce, creating new revenue streams and business models [41]. Digital real estate is not priced upon comparable values with physical property like real estate is, but there are identifiable characteristics such as location in the metaverse, uniqueness, appeal and attraction by users and revenue generation that contribute to the "worth" of digital real estate. The competitive nature of virtual real estate is why property valuation and property management services are available to the public in the virtual marketplace [35], [42]. In addition, blockchain technology is a critical component of a secure and verifiable ownership of digital real estate that is authenticated by non-fungible tokens and multiple verifiable, transparent ownership records [43], as a medium for transferring ownership rights of a securely privately traded ownership. That includes the ability of the blockchain mechanism which captures uniqueness and scarcity of virtual assets also impacts value and trade in the metaverse as well. The emerging areas provided in the metaverse is endless for marketing, education, tourism, and healthcare, just to name a few [35].

2.3. Legal Certainty and Property Rights in the Metaverse

2.3.1. The Legal Essence of Virtual Property

The metaverse has created a new type of property that is entirely intangible, but economically and socially relevant. Fairfield's use of "bitproperty" is when digital property, such as NFTs, replicate the characteristics of traditional property, such as scarcity, exclusivity, and transferability [44]. These digital assets appear to fall under ownership and control through the crypto-managed blockchain, which represents digital ownership through cryptographic validation.

De Filippi and Hassan call this new legal regime "Lex Cryptographia," as it operates as a self-regulating system guided by code instead of state-created legal regimes [45]. Further, they stipulate that blockchain enables a unique type of digital property, as there is no way to intervene with state enforceability. This also brings up important questions about enforcement when there is a breakdown, and is the breakdown even allowed.

2.3.2. Smart Contracts and the Legal Issues Surrounding Them

Smart contracts, self-executing codes that enforce themselves based on certain actions, are typically employed as a means to formalize the conveyance of digital real estate. While smart contracts appear to improve efficiency, and are very convenient and automatable, Werbach and Cornell explain that they lack flexibility and do not contemplate unanticipated circumstances or conflicts that require interpretive judgment [46]. Also, there is no definitive person to rely on for potential remedies or enforcement in the instance of when the smart contract changes to unexpected behavior.

Moringiello and Odinet later argue that the rigidity of code is insufficient to satisfy the legal capacity for contracts in certain jurisdictions, given certain jurisdictions have statutory obligations such as requiring a writing or signature for formal agreements [47].

2.3.3. Disparate Regulatory Frameworks

Regulation of digital real estate operates in vastly different spaces in many jurisdictions. The European Union developed "Markets in Crypto-Assets" (MiCA) which governs digital tokens, digital assets, including NFTs, in a harmonized regulatory framework. Notably, however, the legal framework is still developing as it relates to specific aspects of digital real estate [48]. Wyoming (USA), on the other hand, approved legislation which constitutes digital assets as a type of personal property, subject to issues of inheritance or court placement when seized [48].

In the Middle East, the United Arab Emirates is in a dominant position and has led the regulatory debate and is also developing a new initiative known as “Virtual Dubai” that formalizes a legitimate governance framework for the metaverse [49]. Meanwhile, countries such as Egypt and Iraq are still figuring out how to regulate digital assets in the legal context, putting the legality of property ownership in serious doubt.

2.4. Dispute Resolution and Legal Enforcement in the Metaverse

2.4.1. The Nature of Disputes in Digital Real Estate

Disputes with respect to metaverse real estate typically arise because a smart contract is breached, an asset transfer is fraudulent, a party incorrectly accesses a private key, or the infrastructure of the metaverse platform is malfunctioning. Such disputes occur in spaces governed by few rules with uncertain legal jurisdiction. Werbach and Cornell argue that the decentralization of blockchain undermines the effectiveness of state-based legal remedies when parties are anonymous or located in a transjurisdictional legal landscape [46].

For example, if an NFT is minted and sold related to a digital parcel, and the seller claims that they did not authorize the sale, how can courts order a recission? The transaction was completed automatically via a smart contract, so it is not clear how parties could fix a transaction that executed without judicial oversight. In contract law, parties need to be identifiable, there needs to be a forum from which to execute and enforce remedies, and there needs to be real and effective remedies for justice to take place; these conditions are not always present when dealing with metaverse environments [44].

2.4.2. The Barriers of Traditional Legal Frameworks

As noted above, one of the barriers to resolving disputes in the metaverse is jurisdiction. According to Fenwick and others, metaverse infrastructure functions and exists without borders. Therefore, there is no certainty over which law applies for legal and decision-making purposes, or the jurisdiction of a legal authority to intervene [50] [51]. Although consumers are afforded legal protections generally, there are no consumer protection laws that exist on decentralized platforms or that protect people's interests when they request access to decentralized platforms or the use of decentralized platforms. Users often waive any judicial cause of action by simply agreeing to use the metaverse.

Procedural laws apply when there is a dispute regarding evidence standards or legal representations during the course of arbitration or trial, and it may be difficult for metaverse parties to apply those procedures when they are limited to digital spaces only. For example, if a virtual land parcel is represented as being replicated without a right to do so, what evidence can a person need to rely on as admissible evidence to be hell in a court? Further, there are limited standards to date for determining the digital harm or loss of economic expenditure associated with metaverse real estate [52].

2.4.3. Smart Legal Frameworks and Decentralized Dispute Resolution (DDR)

In reaction to unanswered questions about rights and the lack of laws to clarify issues, scholars and researchers are proposing alternative blockchain-native legal systems that creators are calling smart legal contracts or headlining under Decentralized Dispute Resolution (DDR) platforms. Smart legal frameworks and DDR actions are being promoted as automated, transparent and enforceable alternatives to resolving disputes about digital assets. A notable example of a DDR platform with a strong smart contract following is Kleros, which is an open-source blockchain peer-to-peer based arbitration platform in which jury members are randomly assigned and subject to cryptoeconomic principles of accuracy [53].

Unlike traditional courts, DDR platforms are strictly online and fast. Such advantages are considered to result in lower cost remedies for parties. Nevertheless, such advantages are not without issues invoking a valid legal form of dispute and resolution of the rely parties concerned. Concerns around the procedural fairness of the outcome of the platform, the procedural transparency of the outcome, and whether the outcome complied with the principles of public law have publicly raised questions around the efficacy of the platform. While such platforms are viewed by many as an "off label remedy," it has also been argued that they may not be sensory capable of generating legally or practically enforceable outcomes without appeal or a mechanism in statute or law to enforce any outcome [54].

2.4.4. The Distinction between Platforms versus Private Arbitration

Although the metaverse ideal is a decentralized entity requiring no authority, most users interact through a platform with a centralized entity, for example, the bottom-up organized metaverse for community ownership is Decentraland or the corporate entity backed platform of The Sandbox. These platforms increasingly act as gatekeepers in the enforcement of real actions occurring electronically in the metaverse or the enforcement of private user suspension, verification of ownership to execute transactions. Now, using the horizontal and vertical constructions of ontological positionality, platforms are being ushered in as gatekeepers acting in the same role as private arbitrators or regulatory administrative bodies acting for a broader framework of legal rules [55].

Some researchers appear to support the idea that any platform providing dispute resolution systems be made liable to both parties for their decisionmaking process, similar to subjecting a platform to a legal requirement to implement a due process regime. The researcher lexicon suggests that such legal standards contain meet minimum standards of due process, develop decision-making transparency protocols with an legislative or regulatory authority to determine how to provide processes for effective legal outcomes to join personal accountability as well as greater public accountability [56] [57]. The latter could include publishing dispute resolution processes, reviewing smart contract changes, permitting some form of appeal for a platform decision, which blurs the lines between the private governance of dispute resolution and public accountability.

2.4.5. Growth of Hybrid Legal Frameworks

It is becoming more obvious to legal scholars that hybrid approaches, that combine traditional legal frameworks, with automated technological responses will reach maturity. For example, a lease of property in the metaverse might have both a smart contract and a separate notarized lease that is recognized with a legal jurisdiction. The hybrid construct enables parties to both automate the transaction, and rely on legal enforcement in the courts of nation-states [58].

The hybrid legal framework could also incorporate digital identity assurance, interoperable cross jurisdictional protocols, and international legal collaboration to resolve cross-border disputes. As digital asset regulations are being explored at mechanisms like the WTO and UN, incorporating smart contracts into traditional legal enforcement utilizing established legal processes is becoming a feasible undertaking [56].

3. SUGGESTED FRAMEWORK

To analyze and create a machine learning model to classify metaverse contracts, the first step is to determine the classification objective - for instance, to classify Ownership or Lease contracts. Next, data is collected, and then the preprocessing stages entail cleaning text, extracting text features, and creating labeled data by audit sources. Different classification algorithms (Logistic Regression, Random Forest) are employed, and the classification model's performance is evaluated using accuracy, precision, recall, F1-Score.

3.1. Cybersecurity Considerations and Encoding Relevance

Cybersecurity is necessary to protect digital assets, prevent data corruption, and maintain trust in a virtual instance related to the metaverse in the context of metaverse contracts and the applications of ML. Given that smart contracts are handling high-value transactions and personal ownership information, a high-level of cybersecurity protection is ideal, as this transaction data (especially personally identifiable information) is a prime target for manipulation, unauthorized access, and data breach. Hence, ensuring secure (including ethical) handling of contract data during the preprocessing and modeling stages of the data science life cycle will mitigate weaknesses in the system that could have been pursued by bad actor assets.

One particularly pernicious but important cybersecurity consideration in data up-load is how to properly handle character encoding. When one loads datasets, especially those that incorporate user-generated content, international character sets, or any piece of metadata submitted by a blockchain user, using the correct epsilon standard is very important. Using UTF-8 is a reliable text encoding standard to help ensure that special characters are interpreted correctly and stored properly, without corruption or data-loss.

Not using, or inadequely using the proper character encoding could result in malformed datasets, high latency injection points, and execution errors which can affect overall data integrity and system security. For instance, if there are unexpected characters within a smart contract supplied by a user that isn't processed correctly because of encoding defects, the smart contract could execute where there was not meant to be any logic flow. Similarly, there could be other vulnerabilities such as code injection opportunities.

Which means using `utf-8 as an encoding system during data ingestion is a simple first step that significantly maintains the cybersecurity hygiene, especially where dealing with sensitive contract data in the metaverse that an ML pipeline is affected by.

3.2. Data collection

The dataset collected from Kaggle consists of 1,000 records of contracts for virtual real estate properties in the metaverse. Each record identifies a unique property and contract and includes column identifiers for Property_ID, Owner, Location, Plot_Size(sq_m), Contract_Type, Contract_Start, Contract_End, and Transaction_Value(USD). The dataset spans several platforms within the metaverse, including Decentraland, The Sandbox, and Matrix World, providing a more comprehensive dataset of virtual land transactions. The Contract_Type column became important for classification tasks to distinguish between ownership and leasing contracts. A variety of plots in the dataset was also informative for demonstrating the differences between properties within the virtual real estate market. The start and end dates for the contract allowed for temporal analysis, while Transaction_Value in USD allowed for financial analysis of each contract. In summary, the dataset is formattable as either supervised or unsupervised learning because of its unique properties, particularly suitable for machine learning application, either to classify unique contracts based on the contract_type, predict transaction value based on other features within the dataset, or identify suspicious contracts that may be potentially fraud. The completeness and diversity in the virtual land datasets would prove to be better suited to supervised learning and exploratory data analysis in the emerging marketplace of digital real estate.

3.3. Data Exploration

During the data exploration process, we conducted a comprehensive analysis of the distribution, structure and relationships among the metaverse contract observations. This exploration stage demonstrated valuable perspectives concerning this dataset when we commended the processes of feature engineering and amount of knowledge required by the models we developed. Figure 1 displays the distribution of contract types in our dataset which is a near equal number of Ownership and Lease contracts. In particular, Ownership contracts outnumbered Lease contracts, as there were approximately 500 cases of Ownership and around 450 cases for Lease contracts. Thus, based on the very distinct number of contract types indicates that we have a mixed dataset which can lead to valuable information about both categories of agreements specifically in the virtual real estate market.

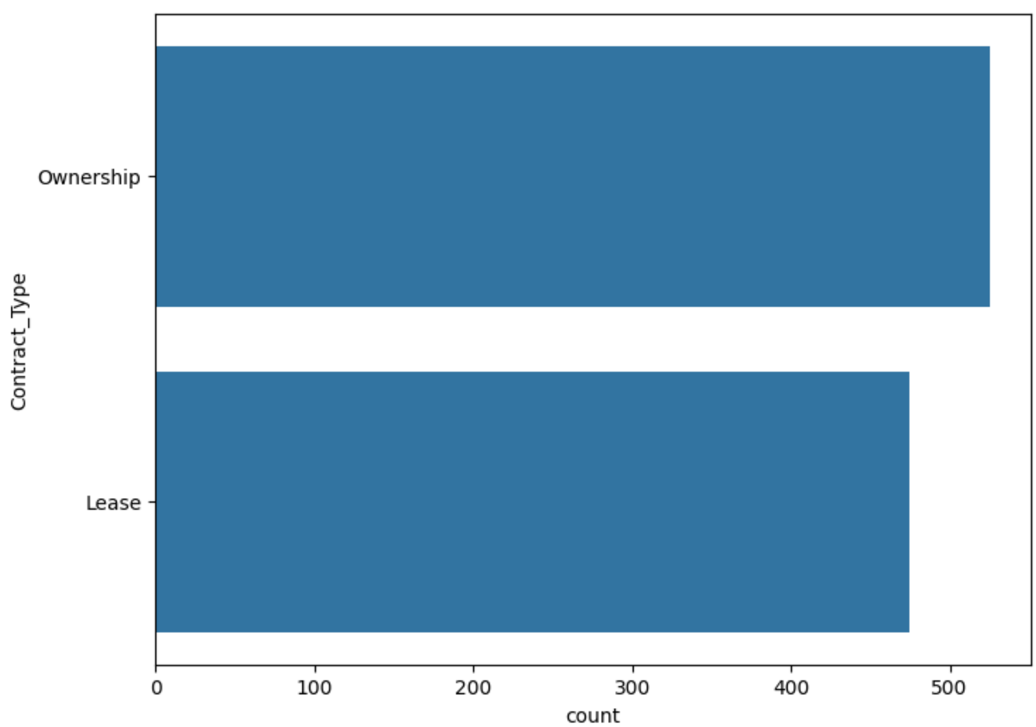

Fig. 1. Distribution of contract type.

Figure 2 shows the relationship between Transaction Value (in USD) and Plot Size (in square meters). The points are spread out over a broad range of transaction values with no definitive linear trend. This indicates that there may be larger plot sizes that correlate with higher transaction values, however, other influences are probably influencing the price. The distribution of points indicates a large variety of transaction values for plots similar in size, indicating that the market dynamics should be further investigated.

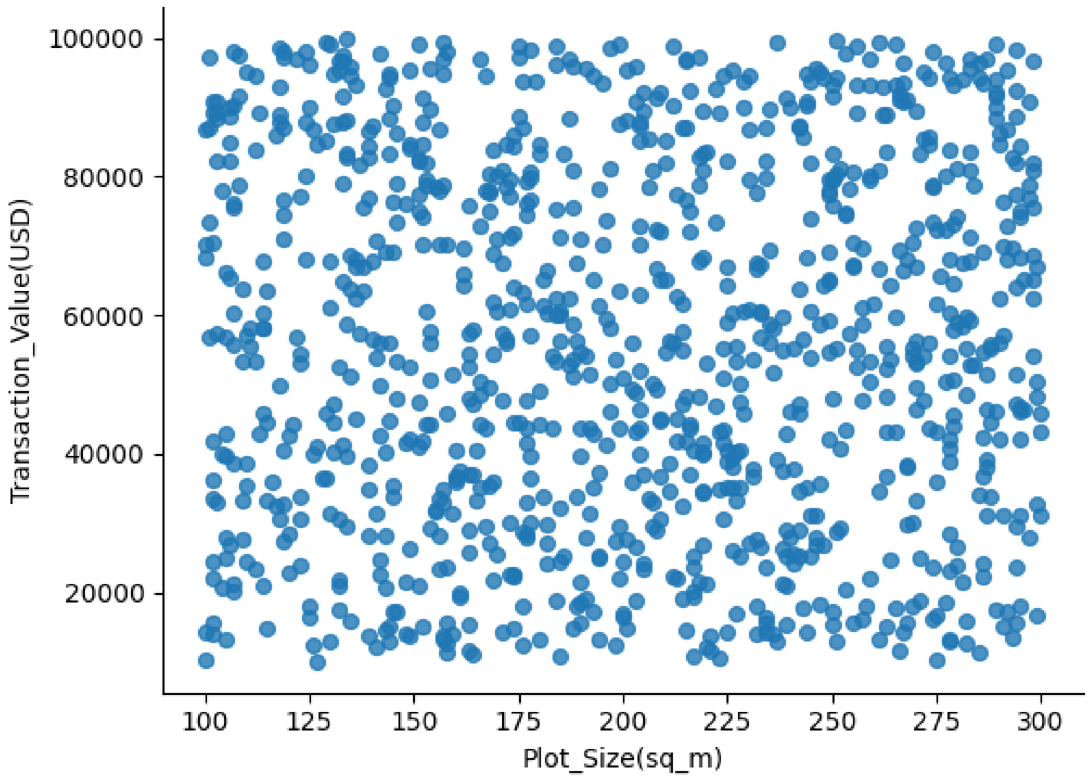

Fig. 2. transaction value vs. plot size

Figure 3 ranks different metaverse venue by their average transaction value alongside their metaverse name. As shown in figure 3, The Sandbox has the highest transaction average followed by NetVRk and Cryptovoxels. Matrix World shows to have the lowest transaction average from the venues listed in figure 3. This type of visual distinction can help signify which metaverse venues are more profitable and can lead to potential further developments of the metaverse, enhancing opportunities to invest further research into determining acceptable market conditions.

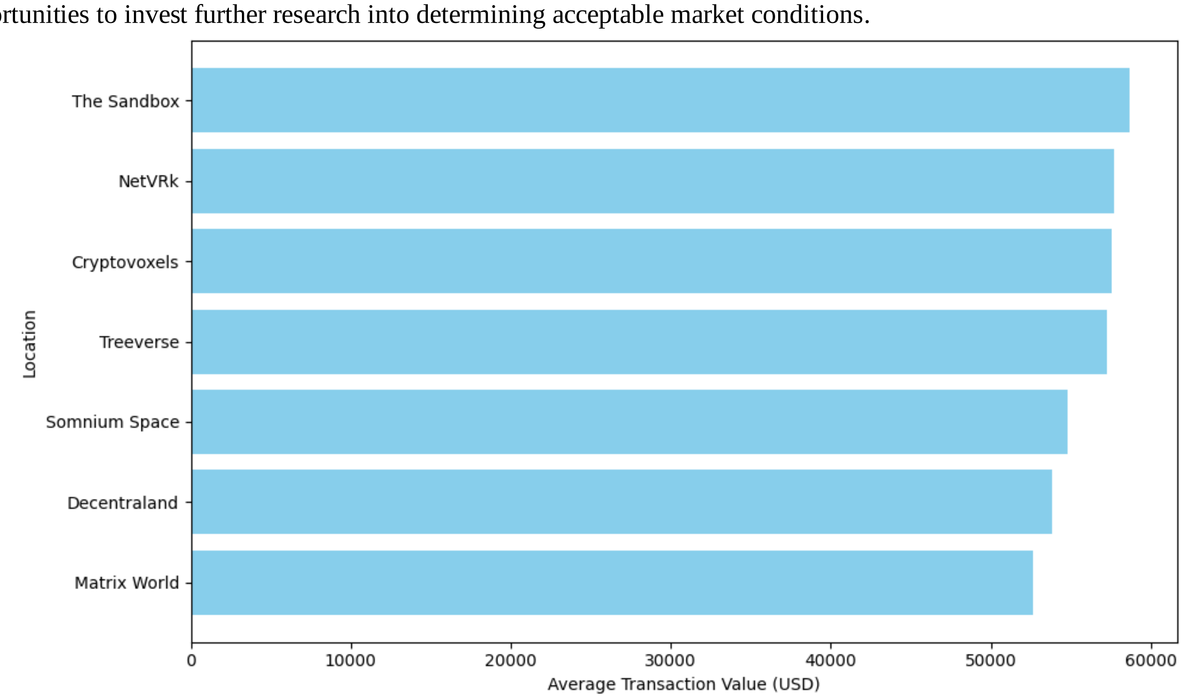

Fig. 3. Locations sorted by average transaction value

The measurements of land size among the metaverse land locations are displayed in Figure 4. Each box depicts the measurements of the interquartile range with the median represented by a line inside the box. The distribution of land size difference can be assessed with The Sandbox and Decentraland recording generally larger land sizes than the platforms with smaller land sizes such as Matrix World and Treeverse. The difference in land size could suggest land development strategies or land availability vary per platform affecting contract types and transaction values.

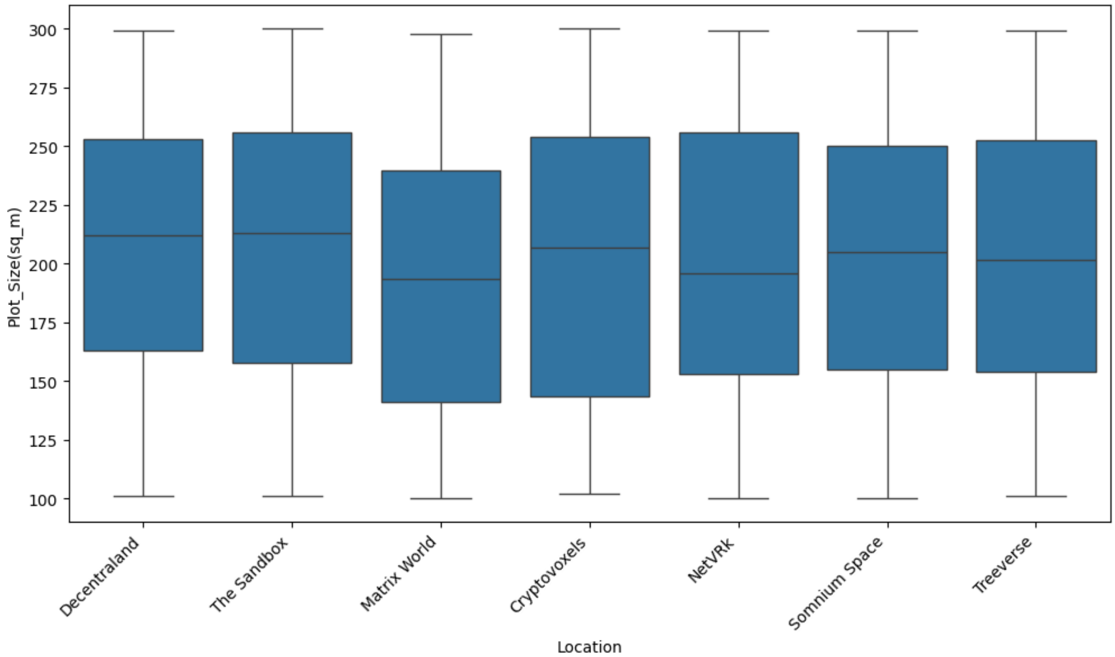

Fig. 4. Plot size distribution by location

The frequency distribution of transaction values (in USD) is illustrated in figure 5. As seen, there are a multitude of prices represented, and overall there appear to be plenty of transactions at price points in all ranges, although there are peaks at various transaction values. Importantly, this shows that there is a steadier range of activity in this market, as the buyer seems to have the range of transaction values not just a couple points in value. The added density curve thickens the overall trends in transaction value frequency.

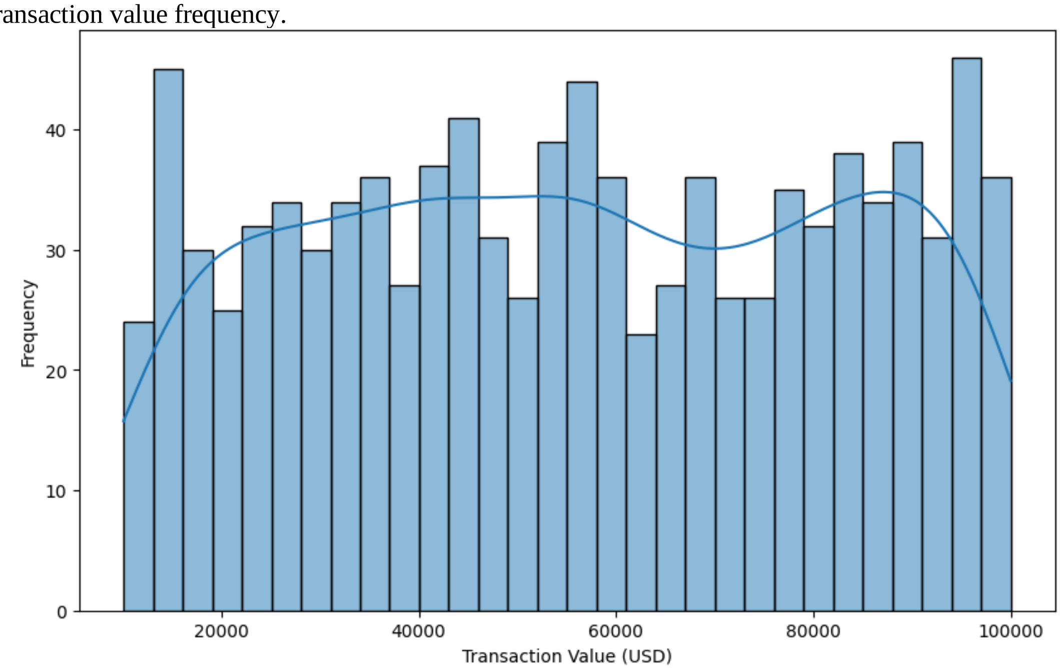

Fig. 5. Distribution of transaction values

The relationship between Plot Size and Transaction Value is depicted in Figure 6, which demonstrated clustering by metaverse. While the plot points represented a full range of transaction values given similar sizes of lots, there are locations that appear to cluster. For example, in Figure 6, the properties in The Sandbox and Decentraland seem to have more higher transaction values given similar plot sizes, reflecting some type of market differences that could inform profitability.

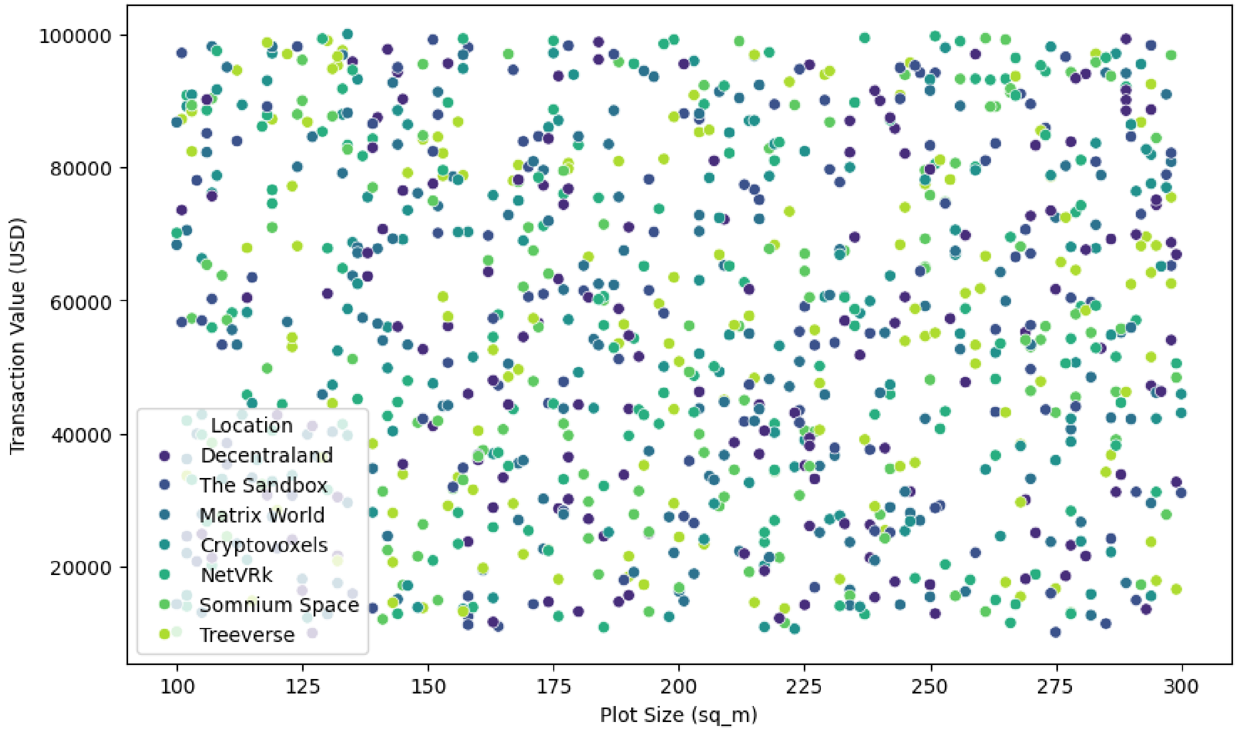

Fig. 6. Plot size vs. transaction value by location

3.4. Data Preprocessing

A series of preprocessing techniques were executed in order to qualify the dataset for machine learning classification. In the first step, categorical features were transformed. Features such as `Location`, `Owner`, and `Contract_Type` were categorical text-based variables. In the case of `Contract_Type`, this feature was the target variable feature so label encoding was applied and it was assigned numerical values to the sale "Ownership" and "Lease" labels. Similarly, for `Location` and `Owner`, one hot encoding was applied and was converted into binary form with new columns created in the data frame. In this case there would be one indicator variable for each unique category, allowing us to locate them in a disloyal manner without prescription ordinal relationships.
The numerical features (e.g. `Plot_Size(sq_m)` and `Transaction_Value(USD)`) were preprocessed by applying standardization to the change feature of all the features in the data frame. Feature scaling was also essential in ensuring that the model building was not adversely impacted due to its variables having much larger scales of magnitude. Using the StandardScaler to standardise the features made sure that they would all have a mean of zero, so that they all had identical variances.
Each feature class was separated to form a training and test set using the proportion between training and test sets. The separation between the sets was standard with an 80/20 split (i.e 80% use for training the model, and 20% of the data will be allocated for testing and identifying model performance- i.e evaluate model performance).

3.5. Applying AI models in classification

To classify contract types in the metaverse dataset, two ML models were invoked: Logistic Regression (LR) and Random Forest (RF) examined below. Logistic Regression was used as a baseline model as it is easy to use and interoperable. The Random Forest model was used as it is an ensemble-based model and can handle complex relationships and high-dimensional feature spaces.

1. **Linear Regression (LR):** Linear regression models the relationship between a variable y and one or more independent variables X by fitting a linear equation [59] [60]:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon \quad (1)$$

where β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients of the independent variables, and ϵ is the error term [61].

2. **Decision Tree Regression (DT):** Decision Tree Regression uses a tree-like model of decisions. Predictions are made by splitting the data into partitions for each node based on the feature that produces the greatest decrease in variance:

$$\text{Variance Reduction } = \text{Var}\ (y) - \left(\frac{n_{\text{left}}}{n}\text{Var}\ (y_{\text{left}}) + \frac{n_{\text{right}}}{n}\text{Var}\ (y_{\text{right}})\right) \quad (2)$$

where n is the total number of instances and where n_{left} and n_{right} are the instances in the left and right branches, respectively [62].

3.6. Evaluation of Performance

To evaluate the performance of the models, four measures, accuracy, precision, recall, and F1-score, are used. These measures are used to evaluate the models' ability to make predictions and the models' ability to reduce false positives and/or false negatives in assigned contracts [63], [64]. Accuracy is calculated on the number of correctly predicted instances divided by all instances to assess the that the model is correct based on the following table:

TABLE I. PERFORMANCE METRICS AND TERMINOLOGY FOR CLASSIFICATION MODELS

Terms	Description	
Confusion Matrix	TP	FP
	FN	TN
Accuracy	(TP+TN)/(TP+TN+FP+FN)	
Precision	TP/(TP+FP)	
Recall	TP/(TP+FN)	
F1-Score	2*((precision*recall)/ (precision +recall))	

- True Positive (TP): The predicted outcome corresponds with the observed outcome. In other words, both the predicted and the observed value are positive [65] [66] .
- True Negative (TN): The predicted outcome corresponds with the observed value. In simple words, both the predicted and observed value are negative [67].
- False Positive (FP): The predicted outcome was wrong. In other words, the predicted value is positive, but the observed value is negative [68] [69] .
- False Negative (FN): The predicted outcome was wrong. To clarify, the predicted value is negative, but the observed value is positive [70] [71].

4. RESULT AND DISCUSSION

To evaluate the classification performance, LR and RF were compared on their accuracy, precision, recall, and F1-score in order to provide a most holistic overview of each model's predictive capability relative to the contract evaluation kept within the metaverse. Regarding LR, we see a solid predictive power by the model where it demonstrated an accuracy of 0.95 suggesting that the model was correct with its predictions 95% of the time. The precision was roughly 0.95, suggesting that nearly all of its positive prediction cases were correct, while the recall value was also equal to 0.95 suggesting the model was able to find 95% of all positively coded cases. Although its F1-score was equal to 0.95 which implies a very even degree of balance had been found with precision and recall, it is fair to conclude that LR would have great reliability as a predictive model, however, conceivably limit its ability to accurately see nonlinear relationships that are more explicit in the contract information embedded in metaverse data ecosystems.

In comparison, RF as provided under the results table, was the most effective model in this analysis, achieving a perfect score of 1.00 for metrics measured; accuracy, precision, recall, and F1-score. Given that the RF model arranged the keeper of all measures perfectly by classifying each instance correctly from the data set without missing anything amidst the complexity within any relationships we kept in the predictions about specifically contracts. This indicates that the RF ensemble model, thereby allowing it to fit to complex patterns better, is considerably more flexible in illustrating more nuanced relationships than alternatives like LR in this case. Additionally, since the RF algorithm relies on the use of all of its tree (decision trees) ensemble types, the incremental fitting nature of these features keeps the model from over-fitting in complex ways. Show in figure 7 were the results.

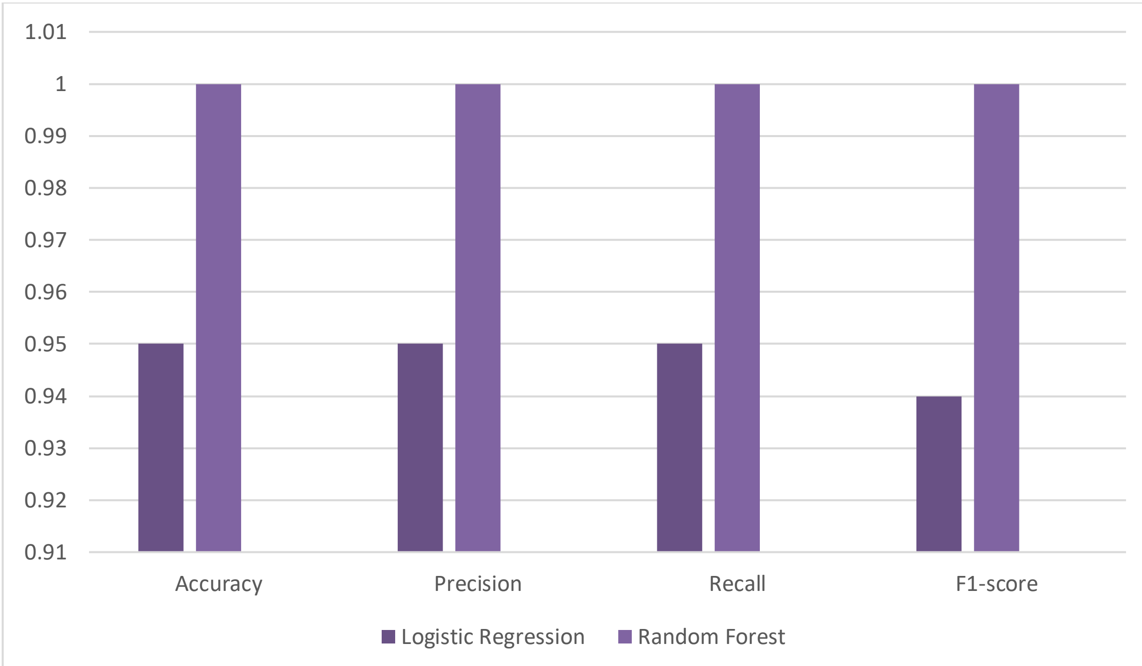

Fig. 7. ML results

Figure 8 displays two confusion matrices, one for the LR model, and another for the RF model, both used to classify ownership status as either "Lease" or "Ownership." In the confusion matrix for Logistic Regression, the model makes a correct classification for 92 classifications of "Lease" and 98 classifications of "Ownership," with 10 and 0 misclassifications, respectively. This is good accuracy, particularly with respect to classifying "Ownership" cases correctly. In comparison, the Random Forest model displays an even higher accuracy with zero misclassifications and all 102 "Lease" cases classified correctly.

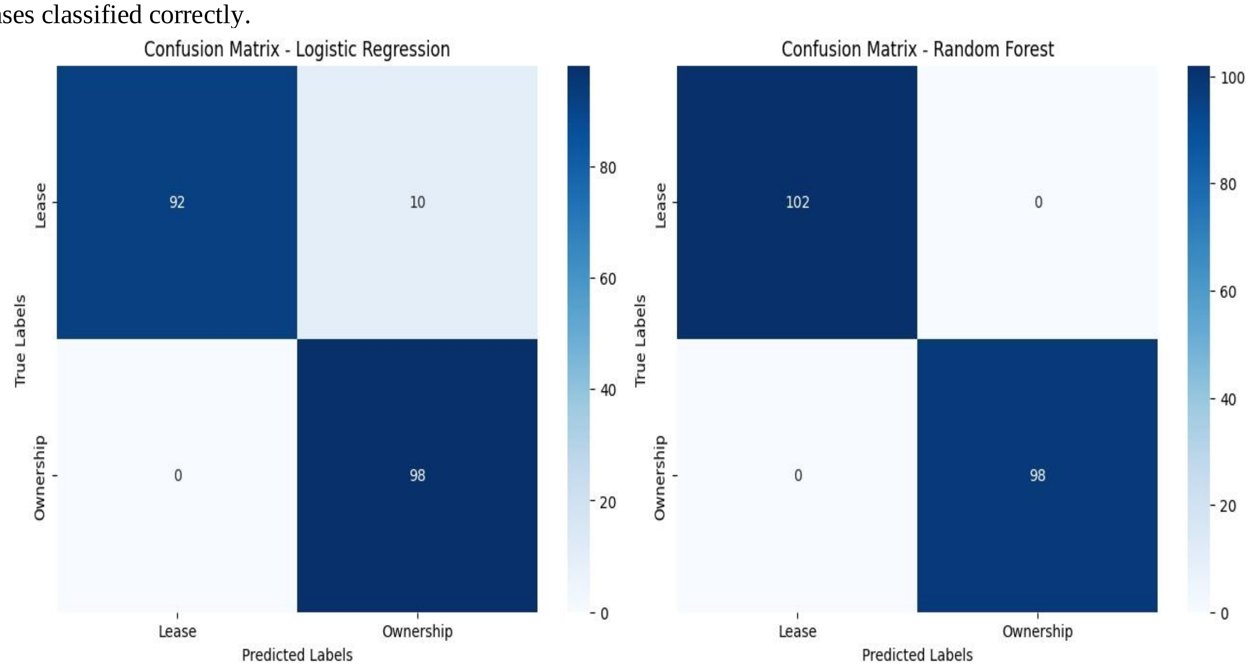

Fig. 8. confusion matrices

Although both models yielded excellent metrics, Random Forest outperformed Logistic Regression across all metrics, hence Random Forest would be the best candidate for predictive modeling applications in the legal and operational parameters for contracts within the metaverse.

5. CONCLUSION AND FUTURE WORK

The study presents a promised framework for classifying Metaverse contracts employing machine learning techniques. Special emphasis was given to cybersecurity and the importance of correctly encoding the data before applying machine learning techniques. The study furthered the research interest of metaverse contracts by examining the virtual real estate contracts across a variety of metaverse platforms. Additionally, while working with some sample data, multiple machine learning models were applied, including LR and RF, as models to classify virtual real estate contracts. The dataset of 1,000 records, examined the variety of contract types, transaction values, plot sizes, and metaverse locations, and set the stages with interesting insights into the relative virtual real estate market.

The dataset analysis illustrated that the RF model outperformed LR on the key performance metrics of accuracy, precision, recall, and F1 in classifying ownership and lease contracts within the metaverse. RF excelled in classifying contracts due to the ability to model complex relationships and density of the data.

In addition to findings, the paper also illustrated how cybersecurity framed the pre-processing stage, and mainly consider how the researchers had to handle character encoding while analyzing the contract text. The study ensured contract data integrity and security in virtual environments for sensitive data. The results present a necessary foundation for future research and practical ventures in developing effective and secure machine learning models in the area of metaverse real estate.

As the metaverse continues to expand rapidly, future work could involve extending the original dataset to incorporate additional metaverse platforms and contract types, creating a more generalized and stronger model. The models could also be evaluated while deployed in real-time, assessing their ability to predict the contract type when presented with contract types in fast-moving, virtual environments. Furthermore, the use of Natural Language Processing (NLP) methods could further enhance the ability of the model's predictive capabilities by using unstructured text data, such as terms and conditions, to classify contracts. This would improve the useability of the model likely setting a researcher up to manipulate a more complex datasets of contracts and enabling documents to be deterred as a bright spot for contract analysis. This would potentially result in a far richer exploration of the actual content within a contract with the un-structured document data. Finally, as cybersecurity is still a major concern when using virtual spaces, future research could focus on ways to refine secure machine learning methods, such as federated learning or homomorphic encryption, in order to protect sensitive contract data while maintaining model efficacy, as this certainly correlates to the need for privacy-preserving machine learning methods in metaverse applications.

Conflicts Of Interest

"The authors declare no conflicts of interest".

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