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Shahram Latifi *Editor*

# ITNG 2024: 21st International Conference on Information Technology-New Generations

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# Advances in Intelligent Systems and Computing

## Volume 1456

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# ITNG 2024: 21st International Conference on Information Technology-New Generations

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# Chair Message

Welcome to the 21st International Conference on Information Technology—New Generations (ITNG 2024). I am delighted to announce that, after a few years of virtual operations, we have returned to an in-person format this year. It is wonderful to see both long-standing members of the ITNG community and new participants alike. ITNG 2024 has attracted high-quality submissions from numerous countries around the globe.

The submissions underwent rigorous review for technical soundness, originality, clarity, and relevance. We are grateful for the expertise of over 50 scientists, both authors and non-authors, who contributed to the review process, ensuring that each paper was evaluated by at least two independent reviewers. Ultimately, 68 papers were accepted for presentation and inclusion in the ITNG 2024 book of chapters. The reviewers' names also appear in the same book.

This year's collection covers recent advances in areas including machine learning, big data analytics, cybersecurity, blockchain technology, data mining, e-health, software engineering, and social computing. In addition to these technical presentations, we are also excited to feature a keynote speaker.

The success of ITNG 2024 owes much to the individuals who organized technical tracks. Dr. Doina Bein played a key role as the conference vice chair. We also acknowledge the contributions of major track organizers and associate editors: Drs. Doina Bein, Allesio Bucaioni, Glauco Carneiro, Luiz Alberto Vieira Dias, Eishta Farjana, Ray Hashemi, Kashif Saleem, Ping Wang, and Hossein Zare.

Further thanks go to Drs. Noha Hazzazi and Poonam Dharam, who were instrumental in soliciting, reviewing, and managing the submissions for their respective tracks/sessions.

We extend special appreciation to Springer for their support in preparing the ITNG proceedings. Our gratitude goes to Michael Luby, Senior Editor and Supervisor of Publications, and Brian Halm, Production Editor at Springer, for their efficient management of our publication order. We also thank Springer Project Coordinator, Kausalya Boobalan, for her diligent work in ensuring the revised chapters were correctly formatted according to the publisher's guidelines. Lastly, we recognize the tremendous efforts of the conference secretary, Mary Roberts, who managed day-to-day affairs and handled a significant volume of correspondence with remarkable efficiency.

I hope you find the ITNG 2024 program both technically enlightening and socially rewarding.

Shahram Latifi
The ITNG General Chair
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# Part I

# AI and Robotics

# Projecting Elliott Patterns in Different Degrees of Waves for Analyzing Financial Market Behavior

Rafael Ribeiro dos Santos, Vanderlei Bonato, and Geraldo Nunes Silva

## Abstract

In the financial market, investors rely on technical and fundamental indicators to estimate the price behavior of an asset to reduce investment risks. Indicators from time series of historical prices are widely used since the past behavior is expected to have a high probability of reflecting itself in future behavior. In this sense, Elliott waves can be used for this purpose since they can describe the patterns and relationships in such historical data. The rules to identify Elliott are well-defined. The challenge remains in projecting patterns with different time frames. Some studies consider Elliott waves for pattern prediction but don't consider how the pattern will be formed. This paper presents a way to project different patterns of lower degrees onto waves of a higher-degree pattern. The solution is a modular model that uses Fibonacci proportions from wavelengths inside the patterns and thus chooses the pattern that is most likely to happen again, considering the type of pattern desired. The results show that the model is accurate when patterns of different degrees are projected.

## Keywords

Elliott waves · Fibonacci proportions · Pattern degree · Pattern projection · Impulse · Flat · Zigzag · Triangle · Wave degree · Financial market

## 1 Introduction

The financial market presents a high degree of volatility related to events that affect the economy, such as natural disasters, political influences, inflation, and financial news [1, 2]. Observing such volatility is essential to understand market trends and how they reflect investor optimism and pessimism. The past trend of an asset can be obtained from its historical data, such as from price and volume variation. However, the challenge remains in projecting the behavior of an asset in different time frames.

Elliott's wave theory is a valuable tool to support investors in decision-making by identifying patterns from historical data [3]. This theory describes the behavior of an asset as waves that form a sequence of patterns that can be further compacted or expanded to create fractals. Analyzing these patterns gives investors insights into the current market development cycle, which is an essential information to predict future movements.

Investors can employ Elliott analysis in various ways, such as predicting the entire next cycle, focusing on specific patterns, or even determining the internal structure of the next pattern. A cycle is formed by an impulsive pattern (Impulse) followed by a corrective pattern (Flat/Zigzag/Triangle).

A way to predict the internal shape of the pattern is by Fibonacci proportions, as they describe the internal behavior between waves [4, 5]. The association between Elliott waves

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and Fibonacci ratios enables an accurate analysis of an asset's history in different time frames.

In the literature, no works focus on projecting waves of different degrees into a pattern, but we can mention some works that focus on the study of pattern prediction. Most financial market behavior prediction works are based on data from technical or fundamental analyses. Thus, we observed the possibility of contributing to the advancement of the state of the art when considering Elliott waves and Fibonacci ratios for the projection of the patterns and subpatterns that make up the behavior of a wave.

This work aims to present a model capable of designing patterns with different degrees of waves, explaining to the user how the pattern will behave in different time frames, such as week, day, hour, and even minute. For this purpose, the model analyzes an asset's history and projects the type of pattern that is most likely to occur through the analysis of the Fibonacci proportions existing in the pattern's history. In this work, we exploit the projection of different degrees from Impulse, Flat, Zigzag, and Triangle patterns. The model generates additional information about the internal shape of each wave of the pattern, constituting its unique contribution.

The structure of this article is as follows: Sect. 2 describes the theoretical foundation related to Elliott waves and Fibonacci proportions, while Sect. 3 covers related work. Section 4 presents our proposed model, followed by the results in Sect. 5. Finally, in Sect. 6, we conclude the article and provide insights for further development.

## 2 Theorical Background

This section presents concepts related to Elliott Waves and Fibonacci Proportions.

### 2.1 Elliott Waves

In 1938, when analyzing the behavior of wave charts in the financial market, Elliott [6] deduced that they had fractal patterns repeated over the time. Elliott believed that the financial market does not behave irregularly but through cycles that reflect the emotional state of investors. He observed that a cycle in the financial market consists of eight waves where the first five are motivating waves, while the last three are corrective waves, known as a 5-3 tuple. This wave behavior is known as Elliott waves. The five motivating waves are identified as wave 1, 2, 3, 4, and 5, while the three corrective waves as wave A, B, and C [7, 8].

Elliott defines five basic patterns to categorize the shape of these two wave sets: Impulse, for the motivation waves, and Flat, Zigzag, and Triangle, for the corrective waves [3]. These patterns can be further categorized and compacted to form complex patterns. It is important to note that Elliot waves are fractals, meaning that a pattern of a lower degree forms a wave per si and the joining of patterns from the current level results in a new wave of a higher degree. The wave terminology varies depending on its degree, as shown in the Table 1.

**Table 1** Examples of wave degrees summarized from [9]

| Wave degree | 5 Impulsive waves | 3 Corrective waves |
|---|---|---|
| Supercycle | [1] – [2] – [3] – [4] – [5] | [A] – [B] – [C] |
| Cycle | [i] – [ii] – [iii] – [iv] – [v] | [a] – [b] – [c] |
| Minor | (1) – (2) – (3) – (4) – (5) | (A) – (B) – (C) |
| Minute | (i) – (ii) – (iii) – (iv) – (v) | (a) – (b) – (c) |
| Minuette | 1 – 2 – 3 – 4 – 5 | A – B – C |
| Sub-Minuette | i – ii – iii – iv – v | a – b – c |

These terminologies can represent patterns from different time frames. For example, a chart of a weekly pattern will have a different terminology than a chart of a daily pattern, which in turn will have a different terminology than an hourly chart. However, all of these graphs represent the behavior of the same asset; only the degree of the wave and the time frame represented vary.

Figure 1 shows a cycle 5-3 at degree level n identified as 1, 2, 3, 4, 5, A, B and C and its fractal at degree levels $n - 1$ and $n + 1$ identified as i, ii, iii, iv, v, a, b and, c, and (1), (2), (3), (4), (5), (A), (B) and (C), respectively. It shows the formation of waves A, B, and C according to the Zigzag pattern (5-3-5).

1. Impulse Pattern: The Impulse pattern indicates the trend in the value of an asset. It consists of a sequence of 5-3-5-3-5 waves, in which the first, second, and third 5 represent waves 1, 3, and 5, while the first and second 3 represent waves 2 and 4. Figure 2 presents an illustrative example of the Impulse pattern.

   The Impulse pattern has three classifications depending on the extensive wave: Wave 1 extensive, Wave 3 extensive, and Wave 5 extensive. Table 2 presents the relationship that waves must have depending on their classification. In this context, L1, L2, L3, L4, and L5 represent the price lengths, while T1, T2, T3, T4, and T5 represent the time lengths of waves 1, 2, 3, 4 and 5 in the Impulse pattern.
2. Flat Pattern: A Flat pattern, characterized by its fractal nature, consists of a sequence of 3-3-5 waves, with the first and second number 3 representing waves A and B, respectively, and the 5 representing wave C. Figure 3 provides an illustrative example of a Flat pattern.

   Neely [9] subsequently introduced classification rules for Flat patterns based on proportional relationships between wave lengths in both price and time, as summarized in Table 3. Comparisons are made relative to a chosen reference wave, allowing the identification of one of the

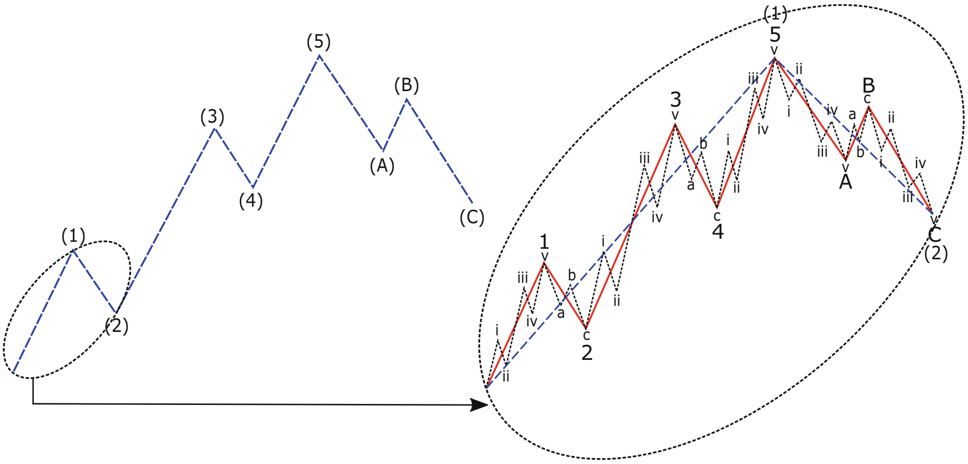

**Fig. 1** A 5-3 tuple of Elliott waves at degree $n + 1$ at the left side and degrees $n$ and $n - 1$ at the right side of the figure showing its fractal structure. The 5 is the set of impulsive waves (1), (2), (3), (4), (5), and the 3 is the set of corrective waves (A), (B), and (C)

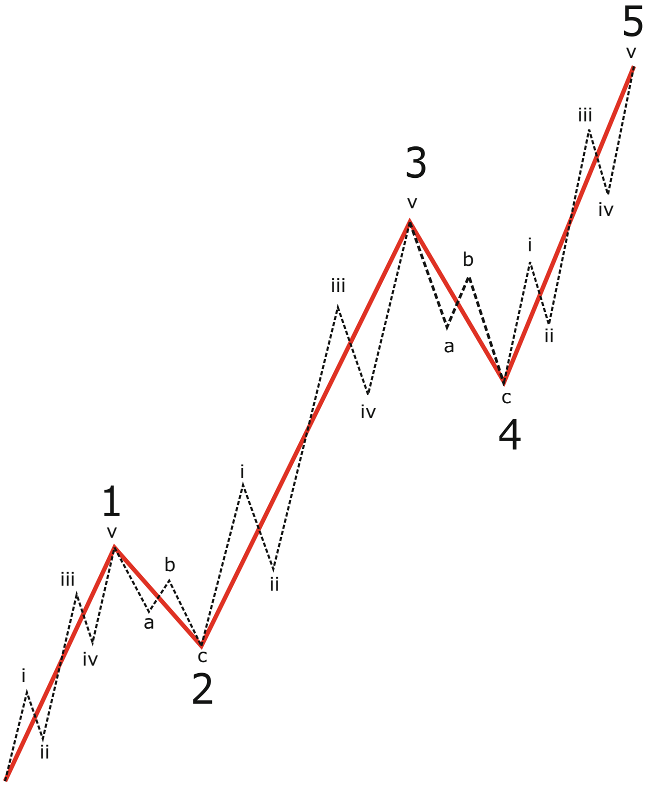

**Fig. 2** Impulse pattern

eight possible Flat types. It is important to note that if no classification is possible based on price relationships, the pattern cannot be considered a Flat pattern. While time is not a factor in type classification, it remains relevant for time prediction. Wave A is not chosen as the reference due to the absence of an adjacent preceding wave.

3. Zigzag Pattern: The fractal of a Zigzag is formed by a tuple of 5-3-5 waves, where the first 5 is the A, the second 3 is the B, and latter 5 is the C. Figure 4 shows an example of a Zigzag pattern.

The formation rules for the Zigzag pattern observed by Neely [9] are summarized in Table 4. It is important to note that wave C end must exceed wave A end, even minimally; otherwise, the pattern cannot be considered a Zigzag. As pointed out for the Flat pattern, there are no formation rules for wave A; therefore, they can assume any value in price and time.

4. Triangle Pattern: The Triangle pattern occurs when the value of an asset moves horizontally; that is, it has slight variation over time. It usually occurs in wave 4 of an Impulse pattern or wave B of Corrective patterns [15]. It consists of a sequence of 3-3-3-3-3 waves, which represent waves A, B, C, D, and E. Figure 5 presents an illustrative example of the Triangle pattern.

As shown in Fig. 5, the Triangle pattern can be classified as Contracting Triangle, which indicates that the asset's value is converging, and Expanding Triangle, which suggests that the value is expanding. Table 5 presents the relationship the Triangle waves must have depending on their type.

## 2.2 Fibonacci Proportions

Fibonacci proportions, derived from the Fibonacci sequence, serve as important retracement and expansion targets for Elliott waves for both price and time [5]. According to [10], there are nine key Fibonacci proportions (0.236, 0.382, 0.618, 0.786, 1.000, 1.618, 2.618, 3.326, and 4.236) that hold significance in financial market analysis. Figure 6 shows two examples illustrating the application of Fibonacci proportions: (I) demonstrates a wave B retracement of 0.618 relative to wave A, (II) presents a wave C expansion of 1.618 compared to wave A.

Pattern formation relies on specific targets outlined in Tables 2, 3, 4, and 5 below and derived from Fibonacci

**Table 2** Formation rules for waves 1, 2, 3, 4 and 5 of a impulse pattern as summarized from [9]

| | Wave 1 Extended | Wave 3 Extended | Wave 5 Extended |
|---|---|---|---|
| Relationship between the length in price (L) of waves 1, 2, 3, 4 and 5. | | | |
| Wave 1 | L1 $\geq$ (1.618 or 2.618 or 3.326) * LPrevious wave | 0.382 $\leq$ L1 $\leq$ 0.618 * LPrevious wave | 0.382 $\leq$ L1 $\leq$ 0.618 * LPrevious wave |
| Wave 2 | L2 $\geq$ (0.618 or 0.786) * L1 | | |
| Wave 3 | L3 $\geq$ 1.618 * L2 | L3 $\geq$ (1.618 or 2.618 or 3.326) * (L1 + L2) | L3 $\geq$ 1.618 * L2 |
| Wave 4 | L4 $\geq$ (0.236 or 0.382) * L3 | | |
| Wave 5 | L5 $\geq$ 1.618 * L4 | L5 $\geq$ (1.618 or 2.618 or 3.326) * L4 | L5 $\geq$ (1.618 or 2.618 or 3.236) * L4 |
| Relationship between the length in time (T) of waves 1, 2, 3, 4 and 5. | | | |
| Wave 1 | T1 = 1.618 * TPrevious wave | T1 = 0.618 * TPrevious wave | T1 = 0.618 * TPrevious wave |
| Wave 2 | T2 = 2 * T1 | | |
| Wave 3 | T3 = 0.618 * T2 | T3 = 1.618 * T2 | T3 = 0.618 * T2 |
| Wave 4 | T4 $\geq$ 0.382 * T3 | | |
| Wave 5 | T5 = 0.618 * T4 | T5 = 0.618 * T4 | T5 = 1.618 * T4 |

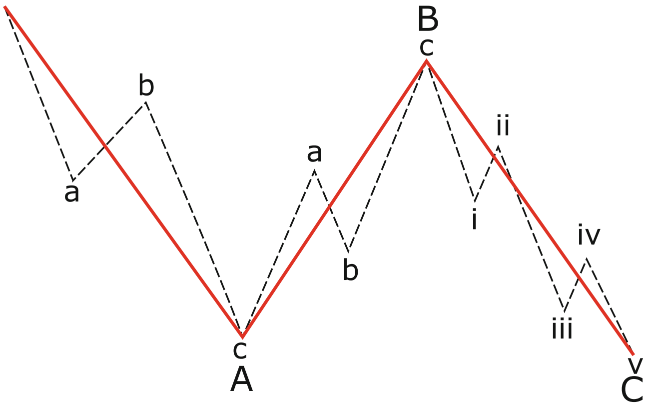

**Fig. 3** Flat pattern

proportions. This paper considers using the nine necessary Fibonacci proportions to cover all possibilities.

## 3 Related Works

This section presents works from the literature that focus on predicting a pattern or its trend. It is essential to highlight that there are no contributions regarding projecting waves of different degrees into a pattern.

D'Angelo and Grimaldi [14] uses Elliott wave theory to predict the exchange rate between Dollar and Euro. Through the graphic visualization, the authors identify Triangle patterns to estimate the pattern's end. The results showed that based on their manual analysis, it was possible to predict the behavior of the wave, as the expected pattern was confirmed. Other works employ neural networks to analyze the history of an asset to identify Elliott cycles (5-3) and thus predict the trend of the future wave [4, 12, 13] but not the specific future price value.

Another work, [11] proposes a model that uses five machine learning models to analyze the Fibonacci proportions and thus predict whether an uptrend or downtrend will occur. The models predict the future trend, and in this information, the Fibonacci proportions are applied to filter the best result. While the model achieves an accuracy of 90% in predicting the wave trend, it does not predict the exact wave value, focusing solely on the trend.

Although these works focus on predicting the behavior of assets, they do not show how the asset will behave in different wave degrees, indicating the pattern's behavior. Thus, our proposed model aims to design patterns with different degrees of waves, presenting to the user how the pattern will behave in different time frames, such as week, day, hour, and even minute.

## 4 Proposed Projection Model

This section presents the proposed model for projecting waves of different degrees. Figure 7 shows the components of the developed model. The model receives as input values the historical data of an asset. Based on this information, the Fibonacci proportion between the waves is analyzed to generate the probability of occurrence of each proportion for each pattern, which indicates which type of pattern has a greater chance of occurring. The Projection Phase is responsible for using this probability to project a smaller degree pattern that represents a single wave of the larger degree pattern.

### 4.1 Pattern Probabilities Identification

This stage is responsible for identifying the probability of occurrence of each Fibonacci proportion between the waves of the pattern. This information is relevant because it presents the behavior of patterns in the history of an asset; that is, it shows which types of each pattern occurred the most. The nine Fibonacci proportions presented in Sect. 2.2 are considered for this.

**Table 3** Formation rules for waves B and C of a flat pattern as summarized from [9]

| Wave B | | Wave C | |
|---|---|---|---|
| Relationship between the length in price (L) of waves A, B and C. | | | |
| Rule | Classification | Rule | Classification |
| 0.618 * La ≤ Lb ≤ 0.80 * La | Weak B-wave | Lc ≤ 1 * Lb | Double failure |
| | | 1.01 * Lb < Lc ≤ 1.382 * Lb | B-failure |
| | | Lc >1.382 * Lb | Elongated flat |
| 0.81 * La < Lb ≤ 1 * La | Normal B-wave | Lc ≤ 1 * Lb | C-failure |
| | | 1.01 * Lb ≤ Lc ≤ 1.382 * Lb | Common flat |
| | | Lc >1.382 * Lb | Elongated flat |
| Lb >1.01 * La | Strong B-wave | 1,01 * Lb ≤ Lc ≤ 1.382 * Lb | Irregular failure |
| | | Lc < Lb | Running correction |
| Relationship between the length in time (T) of waves A, B and C. | | | |
| Tb ≤ 0.618 * Ta OR Tb = Ta OR Tb ≥ 1.618 * Ta | | Tc = Ta OR Tc = Tb OR Tc = Ta + Tb OR Tc = [(Ta OR Tb) * (0.618 OR 1618)] OR Tc = 2 * Ta | |

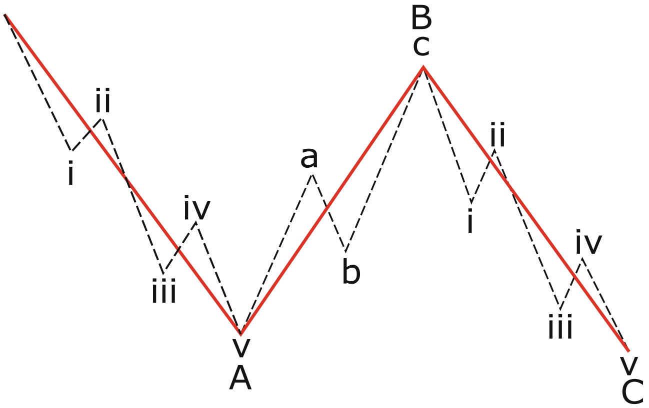

**Fig. 4** Zigzag pattern

The process begins by calculating the proportion between two consecutive waves $L_i$ and $L_{i-1}$. Equation (1) is applied to determine the specific Fibonacci proportion assigned to this proportion. The choice of the Fibonacci proportion is based on the proximity of the computed proportion $P$ to the various Fibonacci under consideration.

$$P = \frac{L_i}{L_{i-1}} = \begin{cases} 0.236 \text{ if } P < 0.309 \\ 0.382 \text{ if } 0.309 \leq P < 0.500 \\ 0.618 \text{ if } 0.500 \leq P < 0.702 \\ 0.786 \text{ if } 0.702 \leq P < 0.893 \\ 1.000 \text{ if } 0.893 \leq P < 1.309 \\ 1.618 \text{ if } 1.309 \leq P < 2.118 \\ 2.618 \text{ if } 2.118 \leq P < 2.972 \\ 3.326 \text{ if } 2.972 \leq P < 3.781 \\ 4.236 \text{ if } P \geq \end{cases} \tag{1}$$

After all waves of each pattern are analyzed, each proportion's probability of occurrence is calculated. This information is then stored in table form so that it is possible to analyze the proportions in the future.

## 4.2 Probability Draw

The probability draw stage consists of drawing a value that will be used to generate a single wave. Initially, a draw is carried out to choose which Fibonacci proportion will be used based on information from the previously generated tables. The greater the percentage of occurrence of a Fibonacci ratio, the greater the chance of this value being chosen. Then, an analysis is performed to verify the pattern classification corresponding to the selected probability. Based on an asset's history, the projected pattern will likely have the highest probability of occurring.

## 4.3 Pattern Projection

Once the probability draw is obtained, this module proceeds to project patterns by following the Elliott rules outlined in [9] and summarized in Tables 2, 3, 4, and 5. Firstly, an initial pattern of a higher degree is created, and then its waves are analyzed so that it is possible to choose the pattern of a lower degree that will be projected in place of that wave. In other words, the waves of the patterns represented by 5 will be exchanged for the Impulse pattern, while those described by 3 will be exchanged for the Flat, Zigzag, or Triangle patterns.

After analyzing the wave that a smaller pattern will replace, the model chooses the pattern that best fits this wave and rescales it to occupy the space in the original wave. To this end, considering the original wave, a rescaling rate for price and time is calculated. This rate is applied to the new pattern to adapt to the wave interval without losing the original Fibonacci proportions used in its projection. The process will be repeated until the original pattern has all its waves replaced by patterns of a lower degree, respecting the rules identified by Elliott. At the end of the process, the initial pattern is presented to the user in different degrees of complexity.

**Table 4** Formation rules for waves B and C of a zigzag pattern as summarized from [9]

| Wave B | | Wave C | |
|---|---|---|---|
| Relationship between the length in price (L) of waves A, B and C. | | | |
| Rule | Classification | Rule | Classification |
| $0.01 * La \leq Lb \leq 0.618 * La$ | None | $0.382 * La \leq Lc < 0.618 * La$ | Truncated zigzag |
| | | $0.618 * La \leq Lc \leq 1618 * La$ | Normal zigzag |
| | | $Lc > 1618 * La$ | Elongated zigzag |
| Relationship between the length in time (T) of waves A, B and C. | | | |
| $Tb \leq 0.618 * Ta$ OR $Tb = Ta$ OR $Tb \geq 1.618 * Ta$ | | $Tc = Ta$ OR $Tc = Tb$ OR $Tc = Ta + Tb$ OR $Tc = [(Ta$ OR $Tb) * (0.618$ OR $1618)]$ | |

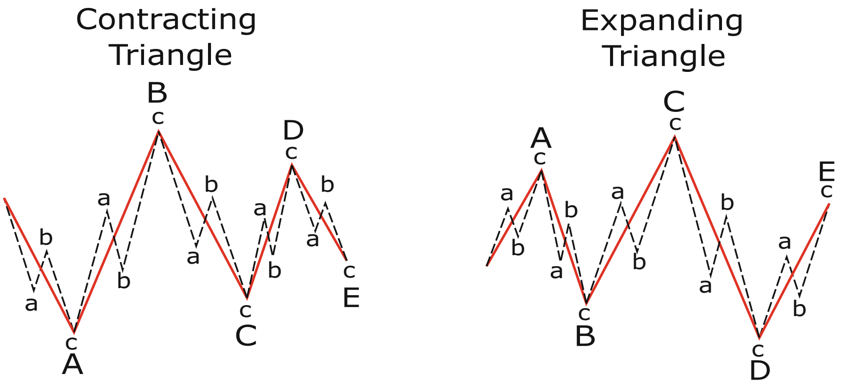

**Fig. 5** Triangle pattern

**Table 5** Formation rules for the triangle pattern as summarized from [9]

| Relationship between the length in price (L) of waves A, B, C, D and E. | | | |
|---|---|---|---|
| Contracting triangle | | Expanding triangle | |
| Classification | Rule | Classification | Rule |
| Horizontal variation | $LB \geq 0.5 * LA$ $LC \leq 1.618 * LB$ | Horizontal variation | $LA < LB, LC, LD$ AND $LE$ |
| | $0.382 * LC \leq LD < * LC$ $LE < LD$ | | |
| Irregular variation | $LB \leq 2.618 * LA$ | Irregular variation | $LB < LA$ OR $LD < LC$ |
| | $LC < LB; LD < LC; LE < LD$ | | |
| Running variation | $LB > LA$ | Regular variation | $LB > LA$ |
| | $LC < LB; LD < LC; LE < LD$ | $LD < LC$ | |

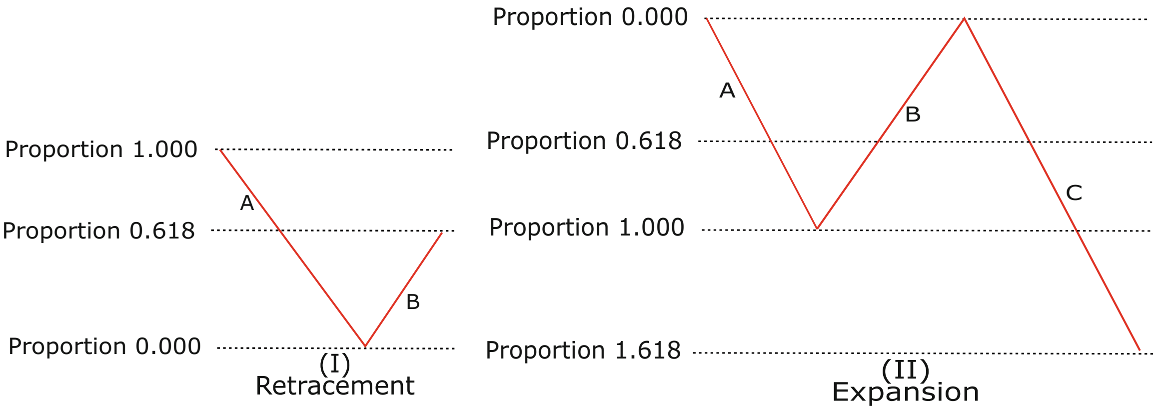

**Fig. 6** Example of a wave retracement at the proportion 0.618 and a wave expansion at the proportion 1.618

## 5 Results

This section presents the results for the Impulse, Flat, Zigzag, and Triangle pattern projections. For validation purposes, we considered the Tables 2, 3, 4, and 5, with the pattern formation rules described in Sect. 2.1. These tables were used to create tables of the probability of occurrence of Fibonacci proportions for each pattern of a hypothetical asset. As we use a hypothetical asset, all Fibonacci proportions have the same probability of occurrence, with the sum of the probabilities being equivalent to 100%. If a Fibonacci ratio does not exist in the rules of a pattern, the probability of occurrence is zero. We designed 100 graphs for each pattern.

At first, real data was not used, as a more in-depth study of the relationship between each wave of patterns is necessary to guarantee the accuracy of the projection. Furthermore, in this case, monthly, weekly, and daily data can be used to project varying degrees of a pattern.

Below are examples of graphs designed for the Impulse, Flat, Zigzag, and Triangle patterns. For the Impulse pattern, the rules defined by Elliott and presented in Table 2, were followed. Figure 8 shows a generated Impulse pattern with Wave 3 extended. It is possible to notice that waves 1, 3, and 5 received a pattern of a lower degree of five waves, corresponding to an Impulse, while waves 2 and 4 received a pattern of a lesser degree of three waves, in this case being Flat and Zigzag. This means that the wave represented in the figure presents an Impulse type pattern, but when analyzed in detail, it is observed that lower-degree patterns of the Impulse, Flat, and Zigzag types form it.

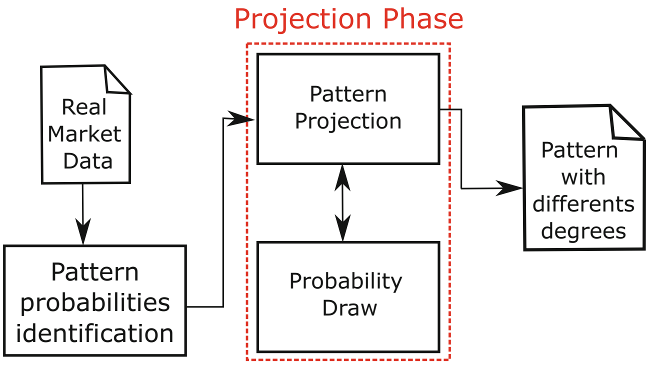

**Fig. 7** Proposed Projection Model. The model's inputs are the patterns identified from the history of an asset. These data are used to analyze the Fibonacci proportion between each wave of the pattern. This proportion will be used in the Projection Phase to project the pattern with the highest probability of occurrence. This process will be repeated for all waves in the pattern, considering the different degrees of the waves. Finally, the designed pattern is presented

Figure 9 shows the graphs designed for the Flat, Zigzag, and Triangle patterns, respectively. It can be seen that all minor degree patterns conform to the formation rules described in Sect. 2; for example, for wave C of Flat and Zigzag patterns, the model projected as a minor degree pattern an Impulse, since 5-wave patterns form wave C.

Through Figs. 8 and 9, it is possible to notice that the presented model can identify each wave that makes up a pattern and the smaller degree pattern most suitable to replace a given wave. As the model follows pre-defined rules, it is possible to ensure the accuracy of the projection.

## 6 Conclusion

This article presents a model for projecting Elliott wave patterns with different degrees. The model determines the most appropriate Fibonacci proportion to choose the best possible pattern for each wave. The results demonstrate that it is possible to design different degrees of patterns considering the history of an asset.

In conclusion, the model presented in this article offers a promising approach to pattern projection. By harnessing historical data and different time frames, the model empowers traders to seize opportunities at each wave formation, unlocking the potential for improved trading outcomes beyond traditional trend analysis.

In future work, the model will be added to a module that analyzes the Fibonacci proportions existing in the history of an asset and uses this information to project the internal behavior of a pattern. Thus, it will be possible to project different degrees of patterns with internal accuracy, which helps traders make decisions in the financial market.

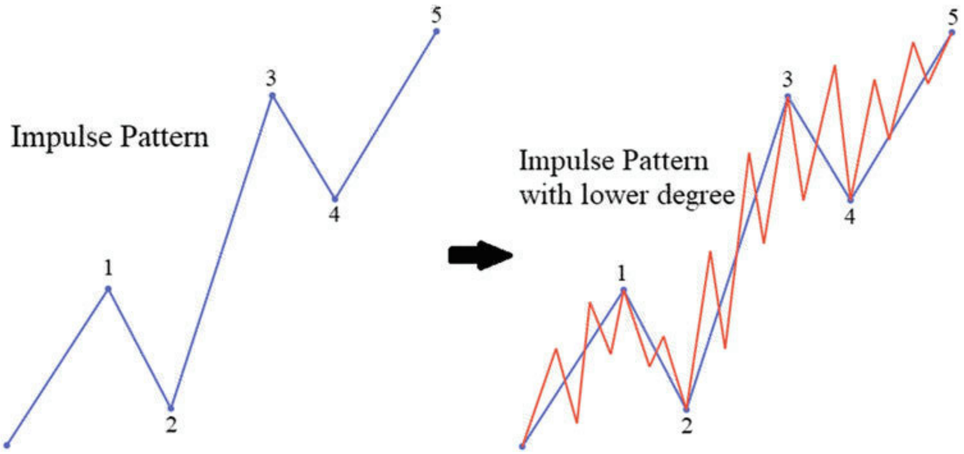

**Fig. 8** Impulse pattern projected and Impulse pattern with waves of lower degrees

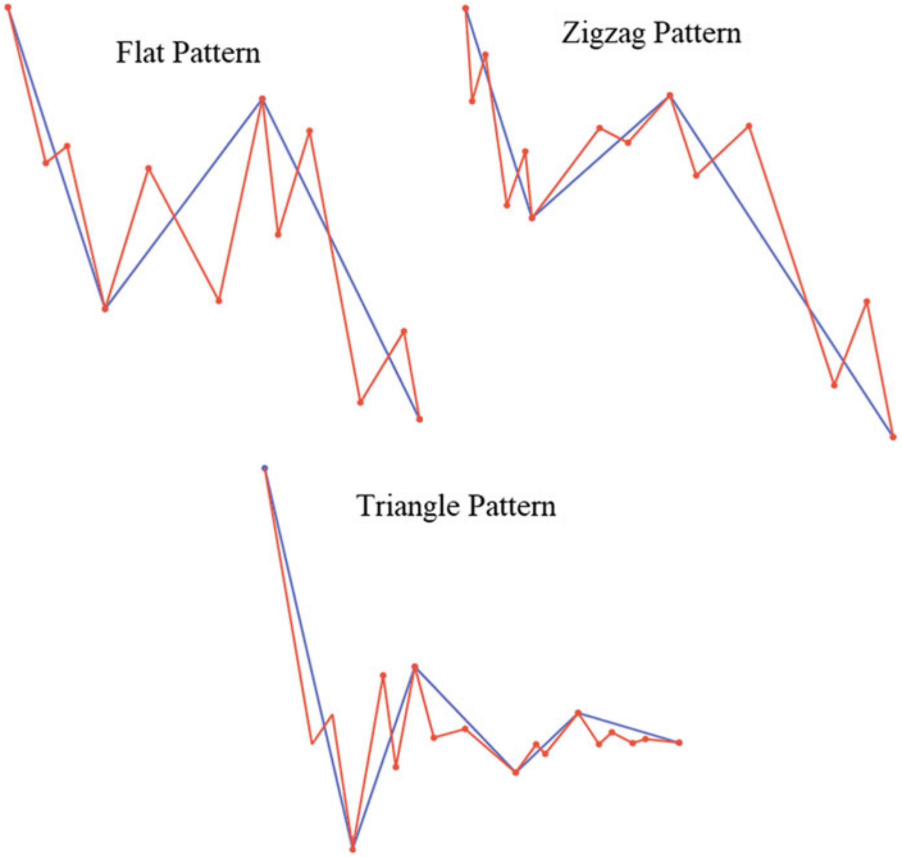

**Fig. 9** Flat, Zigzag, and Triangle patterns projected (blue) and with waves of lower degrees (red)

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# An Integration of Blockchain Web3 and Robotic Process Automation for Property Ownership Traceability

Mina Cu, Johnny Chan, Gabrielle Peko, and David Sundaram

## Abstract

The concept of traceability in property ownership pertains to the establishment of a comprehensive information trail that encompasses transaction history and the associated property ownership data. The challenges inherent in managing property ownership information stem from the complexity of real estate transactions. The properties not only involve ownership status but also encompass critical records, including land reports, records of prior disputes, risk assessments, and the processes related to the property registry. Consequently, ensuring the traceability of property records, mitigating the risks of document forgery, and addressing the potential for erroneous data input and assessment become intricate tasks. Developing a traceable property ownership management system and enhancing the veracity of property ownership records assume paramount importance. Such measures are pivotal for mitigating moral hazards, reducing the occurrence of faulty input, elevating transparency, managing the risks associated with erroneous assessments, and streamlining business processes. In recent years, various traceability mechanisms for ownership have been proposed. Despite the disruptive impact of blockchain technology on enhancing these systems, automated traceability systems, particularly tailored to property ownership management, remain conspicuously absent in the current academic literature. This paper employs a design science research approach to illustrate how an integration framework uniting robotic process automation and blockchain technology can effectively address the issues concerning available ownership traceability systems and related technologies. To this end, we develop and implement a system framework that connects robotic process automation with blockchain Web3 technology. While the proposed solution is rooted in the specific context of property ownership, we explore its potential for generalization to a broader application domain.

## Keywords

Robotic process automation (RPA) · Blockchain · Traceability · Web3 · Property ownership

## 1 Introduction

The term "traceability" was initially used in the supply chain industry to refer to tracking live stocks of goods [1]. In recent years, the traceability of property ownership is generally used to describe an information trail that follows the transaction history as well as trails of property ownership information. Tracing the ownership of a property could be difficult under the shells of privacy rights, document forgery, information withholding, corruption, and other risks. Scholars have argued that a real estate property is a special asset that involves crucial records such as ownership status, land reports, previous disputes, risk assessments, and respective registry processes [2]. Consequently, achieving traceability of property records is challenging [3]. Moreover, the presence of risks associated with faulty input and the moral hazards of document forgery further exacerbates the difficulties of property ownership traceability. The case of the U.S. government struggling to detect the real estate assets of Russian oligarchs serves as an illustrative example of these challenges. Multiple studies have figured out the need for

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a traceable property ownership management system particularly for improving the validity of property ownership [4, 5]. The current systems lack an efficient method to track property ownership, particularly when property ownership data is nested within organizational or institutional silos. Addressing this issue is complex and demands additional research from academia.

In recent years, multiple traceability mechanisms for ownership have emerged, with the prevalent adoption of blockchain technology. Blockchain-based solutions have been introduced for tracking ownership of items such as microchip traceability scheme for the supply [6, 7], supply chain events processing [8, 9], spare parts in manufacturing [10], land registry [2], ownership management [3, 5, 11, 12]. Yet, the automation solutions suggested in current research mainly center on utilizing smart contracts and non-fungible tokens to safeguard ownership identities. This suggests that even while utilizing the advantages of blockchain—such as irreversible records and immutability—for item traceability, the process remains under human management, leading to challenges like moral hazards and a lack of transparency. Furthermore, a comprehensive and automated traceability system, specifically for property ownership management, is noticeably lacking in existing literature.

In this paper, we strive to investigate the traceability use of blockchain technology for surmounting the loophole in the existing property ownership management systems described above. This paper thus embeds the research question:

> *"How can we harness automation technologies like blockchain and RPA to tackle the challenges present in current property ownership tracing systems?"*

We aim to represent problems, develop solutions, and evaluate the system prototype—an integration framework of robotic process automation (RPA) and blockchain technology for property ownership traceability. A design science approach (DSR) is well-suited to our research objectives. By following the DSR approach, we can deliver a set of conceptual artefacts as experimental evidence of blockchain technology's potential in addressing property ownership traceability challenges. Additionally, we will create a series of system artifacts to demonstrate the proof of concept for the proposed conceptual artifacts. In addition, we seek to generalize the solutions to a more general context of the property ownership registry scheme. Blockchain has the potential to revolutionize land ownership registration and property transactions, positioning it at the forefront of global land registration innovation. By embedding robotic process automation to blockchain-based traceability systems, we aim to support public services by an improvement of blockchain applicability and capability for traceability in a broader network structure such as distributed international networks.

The subsequent sections of this paper are structured as follows. In the following section, we offer an in-depth examination of existing blockchain-based solutions for traceability systems, where we provide a concise overview of their system components and the techniques employed for managing ownership. Section 3 outlines the specifics of our research approach—a design science methodology, with a focus on the creation and implementation of research artifacts. In Sect. 4, we undertake a comprehensive critical analysis encompassing the description and evaluation of these research artifacts. This paper also dedicates a segment to discussing our contributions, acknowledging limitations, and identifying potential avenues for further research before concluding in the final section.

## 2 Theoretical Background

### 2.1 Blockchain-Based Traceability Systems

Blockchain technology has been recognized as a promising technological solution capable of bringing about disruptive effects on business processes and operations management [13]. Despite being in its early developmental stages, blockchain has demonstrated its ability to enhance transparency, system immutability, traceability, trust, and overall system improvement [14]. Several studies have figured out that blockchain-based traceability improves ownership traceability, especially in supply chain management [6–9] and in areas where traceability is often the most challenging for intangible items such as the origin of products and ownership [10]. One of the relevant works to our paper that should be mentioned is the study by Lazuashvili et al. [2] on the integration of blockchain technology into a land registration system for immutable traceability. The authors posit that integrating blockchain technology into land registries could significantly transform public-service provision systems. Employing a case study approach, they investigate how blockchain resolves prevailing issues in modern land registry systems and explore the factors crucial for successfully implementing this digital innovation. Leveraging insights from semi-structured interviews and documentation, they analyze the existing blockchain model utilized by the Georgian government. This study effectively tackles challenges in implementing blockchain-based digital solutions within the public land registry service-provision system. However, Lazuashvili et al.'s [2] theoretical approach might not be sufficient to provide practical evidence or solutions.

Several studies have provided blockchain-based solutions for ownership management. Koirala et al. [5] present a general model for a blockchain-enabled supply chain using smart contracts with traceability and ownership management purposes. They have successfully implemented such a model using three smart contracts on an Ethereum platform which delivered infrastructure for a traceability system with ownership verification. However, their approach merely harnesses the advantages of smart contracts for the supply chain. In the same vein, Mohit et al. [12] design and implement a system that protects transaction privacy in a blockchain-based supply chain. Mohit et al.'s [12] system allows product owners to trace the product and enables its transfer via generating symmetric keys while employing product codes and timestamps. The system then uses asymmetric key elliptic curve cryptography for transaction validation and user identification. Sahoo and Halder [3] approach traceability in terms of data ownership. They believe blockchain solutions will help tackle big data ownership management challenges. Sahoo and Halder [3] have developed and implemented a prototype of the system using Solidity on the Ethereum platform. Such system has demonstrated the feasibility and effectiveness of executing gas costs through mitigating watermarking issues in the context of big data. Benarous et al. [11] argue that recording the transfer of vehicles' ownership is essential, but administratively centralized systems are problematic in handling the process. They thus propose a vehicle registration system to save ownership information and the vehicle's descriptions in a public blockchain where all the history of purchases regarding the subject vehicle may be tracked. This system has been implemented and evaluated to show its effectiveness when compared to a centralized registration system. Despite several studies (e.g., Refs. [3, 5, 11, 12]) proposing generalized systems, there exists a research gap in the form of an integration framework for blockchain-based cross-applications to fully leverage blockchain's advantages in ownership traceability and management. Current research reveals an absence of practical evidence for blockchain-based cross-applications specifically aimed at property ownership traceability. Existing studies predominantly concentrate on utilizing the singular advantage of blockchain in tracking items within supply chains. Few studies have directly addressed the challenges related to property ownership traceability. These studies also dominantly rely on existing blockchain-based framework for land registry, which has been introduced and implemented by officials around the globe. Extant research is silent on how to exploit further advantages of blockchain and processes automation solutions to tackle the challenges of property ownership traceability.

## 2.2 RPA and Blockchain

RPA and blockchain have been extensively acknowledged for their advantages in reducing the human factor in business process management [15, 16]. Although both RPA and blockchain contain similar attributes of automation, making them shortlisted in the industrial revolution 4.0 scheme [17], their functionalities are distinctive. Blockchain has put forward a unique approach to automation with the decentralized verification and authentication mechanism [18]. While RPA is predetermined automated tasks, automation in the blockchain is empowered by a group of decentralized users. Aguirre and Rodriguez [19] believe that despite RPA initiation as the software-based solution for business processes automation, existing applications were implemented mostly in the back-office business processes where the customer is not directly involved. Scholars thus should focus on applying RPA to a broader service business process automation framework that integrates both back office and front office layers. Syed et al. [20] argue that RPA solutions have proven that software agents can interact with software systems to precisely reiterate user actions which alleviate human workload and increase operational efficiency. RPA thus has seen a significant improvement in practical implementation and integration with technologies in recent years. However, this practical achievement is asymmetric to a relative lack of attention to RPA in the extant literature. As figured out by several scholars, RPA lacks sound theoretical foundations that support objective reasoning around its development and applications [20, 21]. Furthermore, there are only a limited number of studies on initiatives for integrating RPA and emerging technologies such as blockchain to achieve meaningful advances in the field.

Hofmann et al. [22] mention that RPA software robots follow a choreography of technological modules and controlled workflow operators to operate within IT ecosystems and connect to established applications. The ease of use and adaptability of RPA facilitates the integration of multiple software applications throughout implementations. It is thus vital to establish a framework to address the organizational and IT governance structures. Such a technological integration framework will help address both direct and indirect effects of software robots during automating processes. RPA solutions have been tentatively implemented within other advanced technology applications. Anagnoste [23] integrates RPA with artificial intelligence (AI) and cloud into the services of an organization. With the empowerment of RPA and AI, a process that was mainly not recommended for automation or was partially automated has been fully automated with benefits including financial returns, savings, and customer satisfaction. Existing literature infers that the practical use of RPA per se and/or with other technologies has been seen ubiquitously, while the academic studies seem to fail to catch up with the development pace. Existing studies also show that, although automation in blockchain and RPA solutions are distinguished, these differences do not prevent the integration of the two automation approaches. Madakam et al. [17] suggest that there are many allied technologies, such as artificial intelligence, machine learning, and blockchain technologies working at the background level to support RPA in business operations. The combination of blockchain and automation to improve efficiency and reduce the operating cost has established a seamless integration in multiple aspects such as fraud detection, risk management, and [24]. In this paper, we investigate how RPA solutions might possibly include blockchain to support property ownership traceability and vice versa, i.e., using blockchain web3 platforms and applications to implement RPA solutions for property ownership traceability. This is the area where the current literature is missing. We will tentatively propose an integration framework to fulfill this gap.

## 3 Design of Artefacts

Design science research (DSR) is a methodology driven by the aspiration to enhance the environment through the creation of inventive artifacts and the methods used to develop these artifacts [25]. Using DSR as the methodology, we aim to identify and address the problems of property ownership traceability via establishing a new set of conceptual artefacts upon which the system artefacts will be proposed. Peffers et al. [26] propose a design science research methodology (DSRM) that integrates principles, practices, and procedures to assist IS research in achieving consistency with prior literature, formal process model, problem presentation, and evaluation while doing DSR research. We will follow The DSRM model proposed by Peffers et al. [26] to adopt our research throughout the design phases, namely, problem identification and motivation, the definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. Following this framework, we will deliver clear and consistent definitions, ontologies, boundaries, guidelines, and deliverables research outcomes. This research procedure aims to provide a high-quality design science research project that receives acceptance from both practical and academic audiences in IS and larger design-oriented fields. Starting from identifying problems of the property ownership traceability and motivated by these problems, we define the objectives of extending the current blockchain-based framework for property ownership traceability is to suppressing moral hazard, minimizing faulty input, enhancing transparency, mitigating risks of possible faulty assessments, and improving business processes. The design, development, and evaluation of a prototype framework aiming to connect RPA solution and blockchain Web3 will thus be delivered. This paper establishes a connection between the contextual environment and the design science activities, emphasizing rigor and utilizing a knowledge base such as theoretical foundations, expertise, and facts to construct a solid theoretical groundwork.

### 3.1 Conceptual Framework of the Traceable Property Ownership Management System

The issues identified through our observations in the preceding sections have guided the development of conceptual artifacts. Design artifacts serve the purpose of representing and addressing real-world problems. In our design process, the initial step involved establishing the requirements for a traceable property ownership management system. The foremost objective was to resolve the issues pertaining to property ownership traceability, which remains inefficient in the current management processes. Other essential requirements were associated with the various elements involved in the artifact creation process.

In line with findings from the literature, a pressing need emerged for an integration framework that harmonizes blockchain and RPA to support property ownership traceability. This framework should be implemented without introducing substantial changes to existing technologies, institutions, or stakeholders. Its effectiveness should primarily be gauged from the standpoint of organizations and stakeholders, aiming to enhance transparency, mitigate the risks associated with erroneous assessments, and streamline business processes.

Additionally, the system should reduce the dependency on manual labor and minimize data input errors stemming from moral hazard. The current process involves manual entry and processing of ownership information received from various sources, making it susceptible to such errors. RPA is capable to mitigate such issue. On the other hand, we select blockchain to be the underlying technology due to several reasons: first, blockchain supports multiple information contributors via a decentralized voting mechanism, guarantees immutability of transaction records through its unique computing techniques, and ensures the prevention of adjusting data (i.e., preventing any parties who intentionally and fraudulently adjust or withhold any parts of ownership information). Second, the characteristics of blockchain non-fungible tokens are strongly suitable for implementing an automated distributing system that is correspondent with the structure of the property ownership certification, i.e., one token acts as a block of information with timestamp specifying an ownership certification. Thereby, the system facilitates tracing the flow of property ownership timestamps to prove the consequent entitlement to a certified property ownership information block on the multichain. Due to this paper is rather exploratory research, we will focus on implementing an integration framework for a blockchain network. Such integration framework could be expanded to include further applications and system components. Our key conceptual artefacts will revolve the concepts of blockchain-based traceability and property ownership traceability (POT) and the traceable property ownership (TPO) management system framework.

Automation solutions such as RPA solutions will also be included on blockchain due to the proposed framework will enable us to connect the off-chain RPA solutions to the on-chain blockchain web3 services. This leads us to the concept of integrated RPA. In particular, RPA applications will be allowed to access information regarding property ownership for encryption—mining blocks purposes. Thereby, the proposed blockchain-based solutions will facilitate the on-chain and off-chain data exchange between applications running in the same environment to improve the informational deficiencies occurring in the current system.

### 3.2 Property Ownership Traceability Management System Framework

It has now become essential that property ownership data, despite could be precisely input, might not be able to be tracked. There is a need for a system to assure that ownership information trails of properties are identified. That record-keeping ensures traceability through all or parts of the inter-organizational systems. Thus, the process of generating final ownership can be verified and traceable. The capabilities of the framework for property ownership traceability thus will need to be broad, in-depth, and precise in its specific traceability systems. In this section, the integration of PC applications and blockchain W3 applications enables us to establish a cross-application integration framework (Fig. 1). We use RPA solutions to deliver this integration as follows.

We first establish a cross-application connection between PC apps and blockchain dapps. In the application layer, the RPA bot will be allowed to access transactional processing systems and in-memory databases or databases of available enterprise systems to read and memorize initial data. We then allow the RPA bot to access the blockchain cloud service, where the certified property ownership information will be encrypted using blockchain smart contracts deployed on the middleware—the Ethereum enterprise blockchain. The bot can start scraping and updating ownership data that will be created to be information blocks to complete workflow. Once such data is updated, it will be transferred to mining nodes to be encrypted. The deployed smart contract will use non-fungible tokens as information tags to secure each property ownership information with a unique timestamp and hash number. When the encryption of an information tag completes, a block is mined and added to the multi-chain. Users such as organizational users can access this unreversible information block via a virtual table featured on the blockchain cloud. This would provide authentications of ownership data encrypted as blocks in the blockchain.

This system's application spans across facets. The envisioned system, in its most expansive context, holds the potential to be utilized: (i) to provide origin and ownership and to prevent theft and misrepresentation of property ownership; (ii) for security protection of the purposes of domestic property ownership; (iii) for compliance with local law's requirements; (iv) for managing, surveillance, and controlling foreign capital; (v) for compliance with regulations of international money laundering; (vi) for improvement of property management systems and data governance; (vii) to isolate

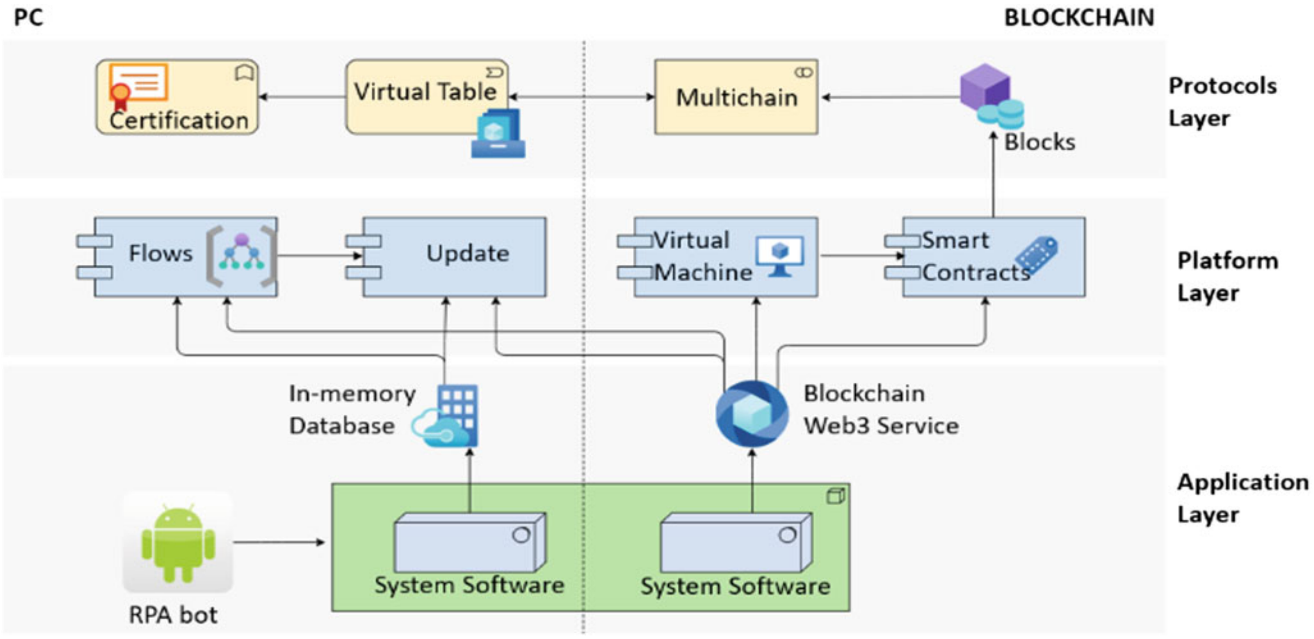


**Fig. 1** Property ownership traceability management system framework

the lack of transparency and moral hazard in the quality-control process; and (viii) to minimize property ownership information errors.

### 3.3 Implementation of the Blockchain-Based Property Ownership Traceability System

This section details the implementation of the blockchain-based property ownership traceability system in a test environment. We will use Moralis server runs on Ethereum Mainnet in the US region and the UiPath RPA solution to construct our system framework prototype.

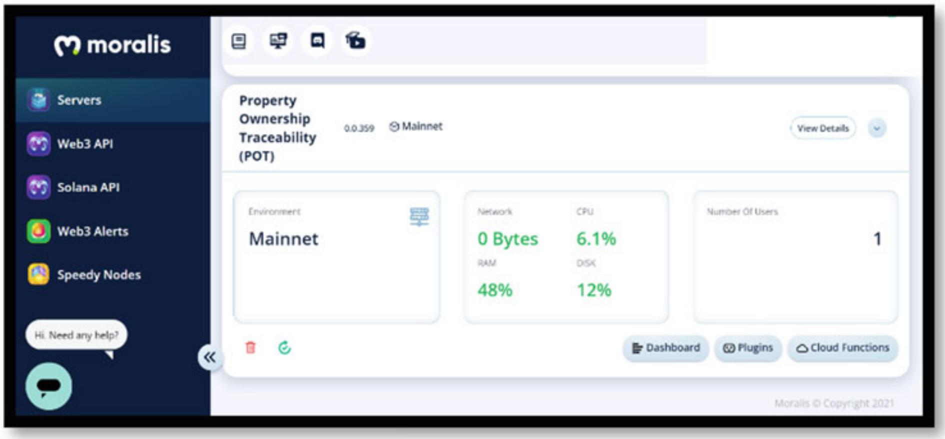
First, we launched a decentralized application (dapp) using Moralis Web3 that can connect to applications installed on an individual computer. Since each dapp has an on-chain component such as a smart contract, and an off-chain component such as a server, we use the Web3 server for two main purposes—collecting data from blockchain cloud virtual table and return queries to users via web service or mobile apps (Fig. 2). The use of Web3 has been justified in terms of bridging technologies that can be applied to different blockchain ledgers independently. Web3 thus is generally used as a tool to achieve greater interoperability between different decentralized systems. In this paper, we aim to use Web3 to authenticate users of blockchain apps and for data aggregation and indexing using a single software development kit (SDK). The SDK will enable us to achieve this goal through a singular solution deployed on the blockchain middleware. Following this setting, the Web3 dapp would help speed up the implementation of the off-chain infrastructure into the on-chain solutions.

Next, we create a webhook to connect Web3 to our local server. We then use the RPA solution—UiPath sequence to log in local serve cloud and start comparing and updating data. It is notable that, the use of RPA solutions is not restricted for accessing the blockchain dapp created using Moralis protocol. Moreover, RPA solutions can also access blockchain cloud services provided by other blockchain-platform-as-a-service providers. In this scenario, RPA solutions also perform as a bridge for cross-chain collaboration and interoperability between decentralized systems.

## 4 Discussion and Evaluation Plan

We are currently in the process of developing a comprehensive property ownership traceability management system. In the first iteration, we attempted to create the Web3 server and to connect it to the local server via webhook. We have also developed an RPA sequence that can log into the local blockchain cloud to scrape and update the off-chain data table. In the future iterations (iterations 2 and 3), we will develop a full-fledged system that allows the RPA bot to perform further sequences such as connecting to the dapp to trigger the block mining processes. In contrast to current solutions, the property ownership management system outlined in this paper enables the fusion of RPA and blockchain, offering a preliminary framework that advances support for business automation, fostering an immutable, transparent, efficient, and traceable property ownership management system. As a result, we present a fresh approach to property ownership traceability within the knowledge base.

Peffers et al. [26] argue that the evaluation of artefacts is an iterative process that requires multiple episodes. Evaluation of designed artefacts also requires both metric and method evaluations. From this perspective, we propose the evaluation scheme for our artefacts in Table 1. The full-fledged system prototype and its workflows will be tested using three eval-



Property Ownership Traceability (POT) 0.0.359 Mainnet

Environment
Mainnet

Network
0 Bytes

CPU
6.1%

RAM
48%

DISK
12%

Number Of Users
1

**Fig. 2** Web3 server for property ownership traceability management system

**Table 1** Evaluation scheme

| Method | Metric | | |
|---|---|---|---|
| | *Technique* | *Iteration* | *Environment* |
| Testing | Black Box and White Box | 2 and 3 | Testing |
| Descriptive | Informed argument and scenarios for feedbacks | 2 and 3 | Real world |
| Prescriptive | Interview with experts | 3 | Real world |

uation methods, namely, testing (Black box and White box), descriptive (feedback analysis), and prescriptive (interview experts).

## 5 Conclusion

This paper uses a design science research approach to represent how an integration framework of RPA and blockchain technology addresses the issues of existing ownership traceability systems. We have developed and implemented a system framework to connect RPA solution and blockchain Web3. While the proposed solution is based on the specific context of property ownership, we discussed how the proposed system framework could be generalized to a broader area of property ownership management. We have demonstrated the proof of concept for our proposed system and outlined a validation plan. Our results illustrate the practicality of this approach, which aims to streamline administrative processes and automate workflows, leading to an efficient and transparent system for property ownership management. The suggested property ownership management system harnesses the potential of RPA and blockchain, providing a framework that enhances support for automating business processes, creating an immutable, transparent, effective, and traceable property ownership management system. Our contribution introduces a novel method for property ownership traceability and lays a foundational direction for future research, particularly in integrating on-chain and off-chain applications and fostering interoperability among decentralized systems.

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