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Fractal Graphs-Based Representation of Tamil Numerals into Mathematical Numerals for Secure Encryption and Decryption Techniques

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Abstract

In times of growing needs of secured information transfer, several innovative cryptosystems have been developed based on advanced mathematical systems. The aim of this work is to construct a graph representation of Tamil numerals based on fractal properties and using the representation model for encryption and decryption purposes. This approach relies on graph theory and fractal mathematics by linking the Tamil numbers to some graph characteristics such as fractal dimension, chromatic number, graph radius and union operation of graphs. The methodology involves the use of classical fractals such as the Cantor Set, Fractal Polygon Graph, Von-Koch Curve, Sierpinski Triangle and Von-Koch Snowflake. Numbers are then assigned to Tamil numerals depending on the graph characteristic, which creates a one-to-one correspondence between Tamil numbers and mathematical numbers. In this case, the encryption process is the transformation of the sequence of Tamil numerals into another sequence of other languages with an algorithm that is known to the sender of the message. In this approach, the input is mapped into mathematical numeral form and the output after encryption will be in mathematical numeral form too. In decryption, reverse mapping takes place. From the experimental study, it could be said that all 10 Tamil numerals were encoded with their unique fractal graph structures. As per the experiments, there was a direct and precise relationship between Tamil numerals and mathematical numerals, the precision of which was calculated to be 100%, both in encryption and decryption. All test cases have proved the reversibility of the framework and absence of data loss in the process. Unique mapping and conversions were confirmed by the performance evaluation studies carried out by the authors.

Keywords: Fractal Graphs, Graph Theory, Tamil Numerals, Encryption and Decryption, Cryptographic Encoding.

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Introduction

Graph theory has proven to be an effective approach in mathematically modeling and analyzing the relationships between the interconnected objects. The application of graphs has been seen in several areas such as engineering (Balakrishnan & Ranganathan, 2012; Sindhu, 2024; Barnsley & Vince, 2013), machine learning (Debnath, 2006; Sporns, 2018; Ortiz et al., 2017; Fernández-Martínez & Sánchez-Granero, 2014; Gil'mutdinov et al., 2017) and even cryptography (Atheeque et al., 2024; Srinivasan et al., 2022; Mishra et al., 2022; Meenakshi et al., 2025) and network sciences (Nandigam & Sundarayya, 2025; Geetha et al., 2020; Suthaharan, 2023; Menandas & Christo, 2023) thanks to the power of representation of a complex structure by utilizing vertices and edges. The utilization of graphs in information security is based on the fact that graphs help in building efficient encryption systems. Graph theory concepts including the graph parameters, graph coding, and matrix-based representation have proven their importance in the secure communication system owing to their ability of making the encryption-decryption process more complex and efficient (Barnsley & Vince, 2013). In the meantime, fractal geometry has come up with new tools for representing structures in the form of self-similarity. The self-similar nature of fractals is commonly found in biological systems like lungs, blood vessels and neural systems among others, and it helps in modeling complex systems (Balakrishnan & Ranganathan, 2012; Sindhu, 2024). The integration of the graph theory and fractal geometry has paved the way for new computational models.

The principal objective of this paper is to develop a new representation method with the help of the fractal graph that represents the traditional Tamil numerals in terms of their equivalent mathematical value to ensure encryption and decryption operations. The proposed method attempts to present a novel method that has a mathematically robust foundation to represent, encode and decode Tamil numerals while enhancing the security of cryptographic applications utilizing the features and parameters of the fractal graph structure.

While graph theory and fractal geometry alone have already established diverse applications in fields such as cryptography, data networks, and pattern analysis, very limited work has been done with respect to exploring the application of graph theory in combination with fractal geometry in the representation and encoding of indigenous numeral systems, such as the Tamil numeral system. It has been observed that traditional methods of encryption usually involve traditional number systems, disregarding the inherent structures of the numerals of these regions (Mishra et al., 2022).

The new hypothesis being proposed in this study is that fractal graphs and graph theoretic encoding schemes have the potential to effectively encode Tamil numerals into mathematical numerals with improved security properties for encryption and decryption process. Another hypothesis is that with the utilization of fractal parameters, the difficulty of decoding the messages would increase.

In this research, the major component is the development of new fractal graph based cryptographic system for encoding Tamil numerals. The systematic way through which the Tamil numerals are encoded with help of graph theory and fractal mathematics into a secure format as mathematical numerals. This will not only involve the application of graph theory and fractal mathematics in cryptography, but it will also bring forward a novel way for encoding traditional numerals systems in secure communication systems.

The article is divided into six broad categories. In the first part that is the introduction, background of the research, research objective, research gap, hypotheses, and contributions to the proposed fractal graph-based cryptographic framework for representing Tamil numerals will be covered. Section 2 includes literature review where studies related to graph theory, fractal geometry, cryptography and encryption techniques related to Tamil numerals are reviewed. In Section 3, fractal structure selection, process of constructing the graph, mechanism for numerically assigning the structures, algorithms used for encryption, decryption algorithm will be introduced, along with an outline of validation framework. In this section, fractal structure selection will be discussed along with the procedures of constructing the graph, mechanism for numerically assigning the structures, algorithms used for encryption and decryption, and the framework for validating whether these structures are valid or not. The assessment of efficiency of the proposed technique is provided in results and discussion section through encryption-decryption examples, performance and security analysis in Sections 4 and 5. Conclusion includes the main conclusions regarding the presented contribution, as well as further potential developments of fractal graph-based Tamil numeral encryption and decryption.

Literature Review

Graph theory has become a vital mathematical basis for modeling systems and solving problems related to communication, cryptography, network analysis, and information security issues (Thomassen, 1986; Balakrishnan &

Ranganathan, 2012). Mathematical properties of graphs such as connectivity, chromatic numbers, and graph theory operations have been used effectively for the design of secure cryptographic models (Sporns, 2018; Atheeque et al., 2024; Srinivasan et al., 2022). Recent research shows that graph-theory-based methods can enhance security in the field by designing secure mathematical models for encoding and transferring data (Pragadeswaran et al., 2024; Meenakshi et al., 2025; Nandigam & Sundarayya, 2025). The area of fractal geometry is receiving a great deal of interest owing to its distinctive ability to mathematically represent self-similar and complex structures (Barnsley & Vince, 2013; Debnath, 2006). Fractal dimension and graph that have been created using fractal have been explored widely in various applications such as signal processing, image analysis, pattern recognition, and secure communication systems (Fernández-Martínez & Sánchez-Granero, 2014; Gil'mutdinov et al., 2017). The mathematical structure and recursion capability of fractals make it a promising subject area for applications in cryptography because of the need for randomness and uniqueness in such algorithms (Ortiz et al., 2017). Graphs and cryptography have been integrated to propose novel encryption algorithms that involve graph parameters, fuzzy graphs, and hypergraphs (Meenakshi et al., 2025; Nandigam & Sundarayya, 2025). These encryption algorithms utilize multiple layers of mathematics in encryption and decryption to improve security performance. Moreover, promising findings have been established regarding homomorphic encryption and graph-based intelligence models towards improving security and reliability in data communication (Pragadeswaran et al., 2024; Sindhu, 2024). Research in Tamil cryptography has received considerable attention in recent times. Cryptographic techniques for hybrid symmetric algorithms, Tamil language encoders, and cryptography with respect to linguistic properties in Tamil language have been introduced to encrypt regional language data (Geetha et al., 2020; Suthaharan, 2023). In-depth research into Tamil cryptographic dictionaries, curve cryptography in Tamil language, and mathematical cryptography for the language has been conducted (Menandas & Christo, 2023; G A et al., 2024). Nevertheless, most techniques have been directed at encrypting data from texts and languages while minimal efforts have been done on numerals. Although remarkable advancements have been made in graph cryptography and fractal geometry, there have been no notable attempts to utilize fractal graphs for encryption and decryption of numerals in Tamil language. This paper addresses this issue and develops a new graph-fractal based technique that represents Tamil numerals and conducts encryption and decryption using graph-theoretic and fractal parameter.

Methodology

Research Framework

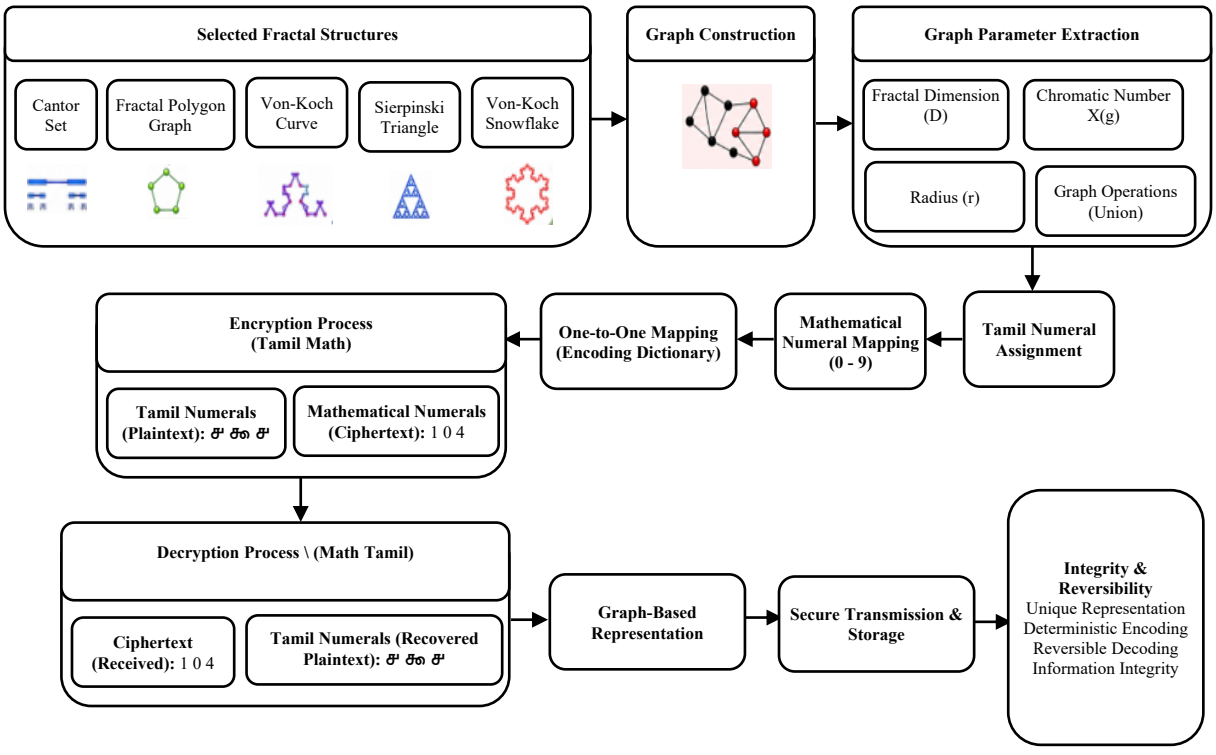


Fig. 1: Overall Framework of Fractal Graph-Based Tamil Numeral Encryption and Decryption System

A new graph-based fractal cryptography approach is used in this research for the purpose of representing Tamil numbers and converting these numbers to mathematical numbers. This is done through the use of graph theories along with fractal geometry, in order to develop a method for encoding and decoding the symbols. Fractals are considered to be graphical structures where their mathematical elements such as fractal dimension, chromatic number, radius, and graph operations are used to assign values to Tamil numbers.

Overall Process of Proposed System is given below in fig. 1 that consists of choosing the fractal structure, calculating the graph parameter, assigning Tamil number to the graph, mathematically assigning the number to the chosen graph, encryption of the message, decryption of message and finally giving the output message.

Mathematical Properties of Fractal Structures

A number of classical fractals structures have been used in this proposed approach due to their inherent properties like self-similarity and mathematical property.

Cantor Set

Cantor's set is a traditional example of a fractal where the middle third of a line is cut off at each step of construction. After that, this process is applied to just one line segment, forming a very irregular structure, which has infinitely many points but its total length equals zero. Despite the simplicity of this figure, there exists a certain definition of the Haus Dorff fractal dimension for this set, and it is one of the simplest fractals (Balakrishnan & Ranganathan, 2012; Sindhu, 2024).

The fractal dimension of the Cantor set is shown as equation (1)

$$D = \frac{\ln(2)}{\ln(3)} \approx 0.6309 \quad (1)$$

For the proposed encoding scheme, the computed value is approximated to the numerical value 1 and assigned to the Tamil numeral ௧.

Von-Koch Curve

The Von-Koch curve is a fractal curve that is continuous but not differentiable everywhere. It is made using a process where a line is divided into thirds, and then the middle third of the line is replaced by the other two sides of an equilateral triangle. This process continues indefinitely, leading to a curve with infinite length but finite area (Balakrishnan & Ranganathan, 2012; Sporns, 2018).

The fractal dimension of the Von-Koch Curve is shown as equation (2)

$$\mathrm{D} = \frac{\log 4}{\log 3} \approx 1.2619 \quad (2)$$

The graph representation derived from the first iteration of the Von-Koch Curve is utilized in constructing the numerical assignments corresponding to Tamil numerals ௳ and ஆ.

Sierpinski Triangle

Sierpinski Triangle, this is a fractal design created from an equilateral triangle. First, lines are drawn connecting the midpoints of all three sides to form four equilateral triangles. The central triangle is then removed, but its outline remains. This process is applied to each of the remaining three triangles to get a complicated fractal pattern (Balakrishnan & Ranganathan, 2012; Ortiz et al., 2017).

The fractal dimension of the Sierpinski Triangle is shown in equation (3)

$$\mathrm{D} = \frac{\log 3}{\log 2} \approx 1.584 \quad (3)$$

The graph representation of the Sierpinski Triangle possesses a chromatic number of four and is therefore assigned to the Tamil numeral ௪.

Von-Koch Snowflake

The Von-Koch Snowflake is obtained using the same method used to obtain the Koch curve for all three edges of an equilateral triangle. In each step, the three segments of the previous edge are divided into three, with the central part

being replaced by two sides of an outward equilateral triangle. The resulting figure will have a very complex shape with a finite area but an infinite perimeter (Balakrishnan & Ranganathan, 2012; Sindhu, 2024).

The fractal dimension of the Von-Koch Snowflake is identical to that of the Von-Koch Curve, shown as equation (4):

$$D = \frac{\log 4}{\log 3} \approx 1.2619 \quad (4)$$

Within the proposed framework, the radius of the first-iteration snowflake graph is employed for assigning the numerical value corresponding to the Tamil numeral ൯ (Sporns, 2018; Ortiz et al., 2017).

Fractal Polygon Graph

A fractal polygon graph is said to be a non-empty graph that has self-similar conditions. It is a simple connected graph that has p^2 number of vertices, such that $p \geq 3$. The major difference between a Fractal polygon graph and a general fractal is that a Fractal polygon graph has a fractal dimension of two.

The fractal dimension is therefore represented as

$$D = 2$$

This property is used to assign the numerical value 2 to the Tamil numeral ൨.

Construction of Fractal Graph Representations

As per the coding technique discussed above, numbers are assigned to Tamil numerals using graph theoretic parameters of chosen fractal designs. Fractal dimension, chromatic number, radius of a graph, and the operation of graph union are some of the parameters used for assigning numbers to Tamil numerals.

A trivial graph with just a single vertex is taken initially as a representation of the Tamil numeral ൦. This is because the trivial graph has only one isolated vertex, and no further analysis on its structure is required to represent the number 0.



Fig. 2 (a): Trivial Graph Representation for Tamil Numeral ൦

A single-point graph that represents both the Tamil numeral ൰൦ and the mathematical numeral 0, as depicted in fig. 2(a).

Afterward, the first generation of the Cantor set will be considered. From Definition 2.1, the fractal dimension for the Cantor set is approximately equal to 0.6309, and rounding it off will yield an integer value of 1. Hence, the fractal is assigned to the Tamil numeral ൧(fig. 2(b)).

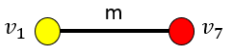


Fig. 2 (b): Cantor Set Representation for Tamil Numeral ൧

First iteration of the Cantor Set where the fractal dimension is denoted by D≈0.6309, associated with the number 1.

Then, an analysis of the Fractal Polygon Graph is made. According to Definition 2.5, the fractal dimension of this graph is 2. Thus, the Fractal Polygon Graph will be associated with the Tamil numeral ൨, which corresponds to the mathematical number 2 (Fig. 2(c)).

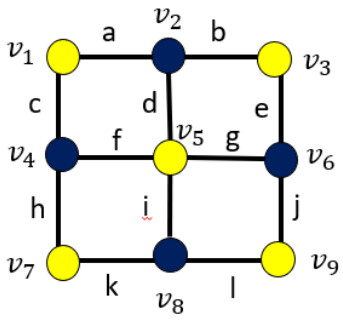


Fig. 2 (c): Fractal Polygon Graph Representation for Tamil Numeral ೭

Fractal Polygon Graph with fractal dimension D = 2, which corresponds to the numeric digit 2.

For constructing the representation of the numeric digit 3, the complementary graph of the first iteration of the Von-Koch Curve is used. The complementary graph comprises five vertices and six edges and has a chromatic number of 3, i.e., $\chi(G) = 3$. Thus, this graph is associated with the Tamil numeral ൩ (Fig 2d).

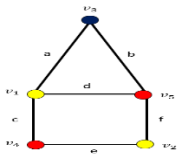


Fig. 2 (d): Complementary Von-Koch Curve Graph for Tamil Numeral ൩

Complementary Graph corresponding to the first generation of the Von-Koch curve, where the chromatic number is 3.

The Sierpinski Triangle is used to get the numerical digit 4. The graph of the Sierpinski Triangle has a chromatic number equal to four, that is, $\chi(G)=4$. Therefore, this graph corresponds to the Tamil numeral ൪ (Fig. 2(e)).

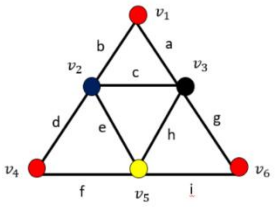


Fig. 2 (e): Sierpinski Triangle Graph Representation for Tamil Numeral ൪

Graph representation of the Sierpinski Triangle with a chromatic number of 4, representing the numeric value 4.

The graph construction for numeric value 5 is done through a union operation between the Cantor Set and the Sierpinski Triangle, resulting in the graph being represented by the Tamil numeral ൫ (see Fig. 2(f)).

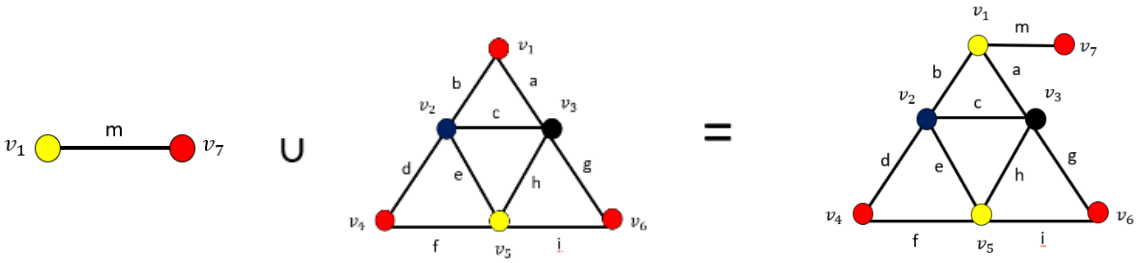


Fig. 2 (f): Union of Cantor Set and Sierpinski Triangle for Tamil Numeral ൫

Composite graph that arises from the union between the Cantor Set and the Sierpinski Triangle and is designated with the numerical value 5.

For the numerical value 6, the analysis is done on the first iteration of the Von-Koch Snowflake graph. It has been found out that the radius of the graph is six and consequently it is given the Tamil numeral ரு(Fig. 2(g)).

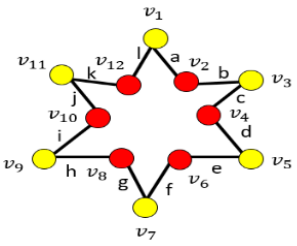


Fig. 2 (g): Von-Koch Snowflake Graph Representation for Tamil Numeral ரு

Graph for the first iteration of the Von-Koch Snowflake with radius 6.

Number seven is derived from the union of the Cantor Set with the first iteration of the Von-Koch Snowflake graph. The generated graph is represented by the Tamil number ஏ (Fig. 2(h)).

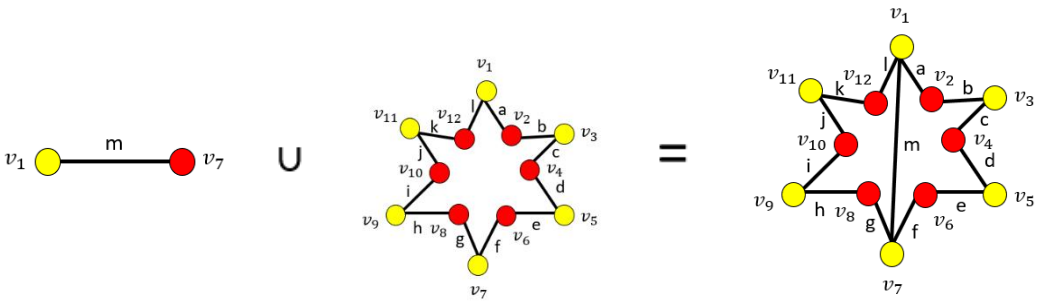


Fig. 2 (h): Union of Cantor Set and Von-Koch Snowflake Graph for Tamil Numeral ஏ

Composite graph constructed using both the Cantor Set and Von-Koch Snowflake graphs. Represents the number seven.

Representation of the value eight through the use of the Von-Koch Curve graph for the first iteration. The graph has five vertices and four edges and is mapped to the number Tamil அ (refer to Fig. 2(i)).

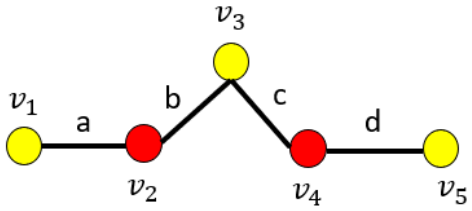


Fig. 2 (i): Von-Koch Curve Graph Representation for Tamil Numeral அ

Graph of the first iteration of the Von-Koch Curve assigned with the value of 8.

Lastly, the graph union of the Cantor Set and the graph of the first iteration of Von-Koch Curve is computed. This union graph is then assigned the Tamil numeral ஒ or 9 mathematically (Fig. 2(j)).

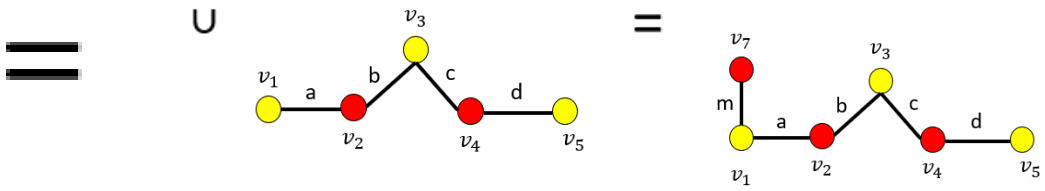


Fig. 2 (j): Union of Cantor Set and Von-Koch Curve Graph for Tamil Numeral ஒன்பது

Composite graph obtained through the union of the Cantor Set and the Von-Koch Curve graph, assigned the numerical value 9.

Tamil Numeral Encoding Model

A bijective mapping is established between Tamil numerals and mathematical numerals using the extracted fractal graph parameters. Let

$$T = \{0,க,உ,ஈ,ச,ஞ,கூ,எ,அ,ஒ\}$$

denote the set of Tamil numerals and

$$M = \{0,1,2,3,4,5,6,7,8,9\}$$

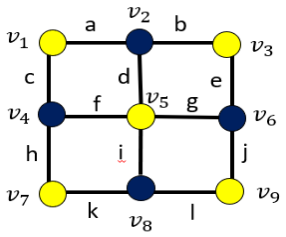
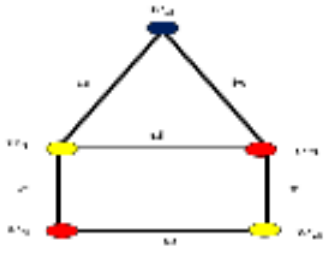
Represent the corresponding mathematical numerals.

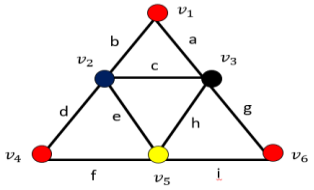
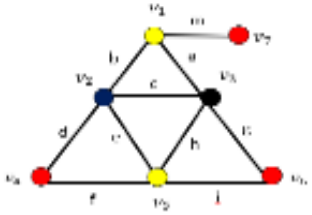
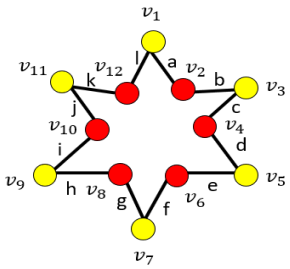
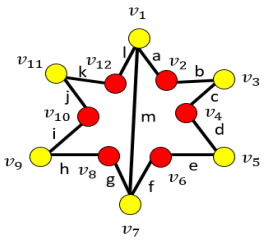
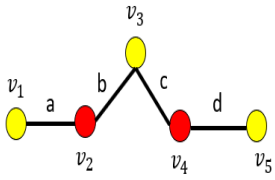
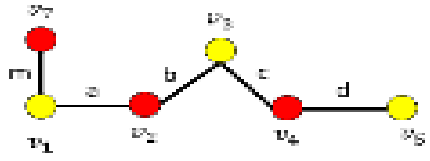
The encoding function is defined as

$$E: T \to M$$

where each Tamil numeral is uniquely associated with a fractal graph representation and its corresponding mathematical value.

Table 1: Fractal Graph-Based Mapping of Tamil Numerals to Mathematical Numerals

Tamil Numerals	Math Numerals	Graph structures
0	0	
க	1	
உ	2	
ஈ	3	

சு	4	
டு	5	
கூ	6	
எ	7	
அ	8	
கை	9	

In table 1 illustrates the one-to-one mapping of each Tamil numeral and its mathematical counterpart through the proposed fractal graph approach. A fractal graph or property, such as fractal dimension, chromatic number, graph

radius, and graph union, will be assigned to each Tamil numeral that will then serve as an encoding dictionary used for encryption and decryption procedures in this research.

Encryption Process

The encryption process involves the conversion of a sequence of Tamil numerals into mathematical numerals, which are considered as ciphertext, using the existing encoding table. In other words, each Tamil numeral will be converted to its corresponding numerical value based on the fractal graph parameter assigned to it.

Decryption Process

The decryption process acts as the reverse of encryption, wherein a mathematical ciphertext will be converted to Tamil numerals. This is done using the same fractal graph assignment table.

Validation through Case Studies

Validation is done by considering some examples of Tamil numeral sequence sets. The experimental results prove the successful encryption and decryption of the proposed method in Tamil numerals. Hence, the validation proves the uniqueness, correctness, and invertibility of the proposed method of fractal graph-based cryptographical representation of Tamil numerals. The validation also proves that graph theoretic parameters obtained from fractal graphs can be used as a safe encoding key for representing the Tamil numerals.

Results

Fractal Graph-Based Cryptographic Representation of Tamil Numerals

The proposed method of Fractal Graph Based Cryptographic Representation of Tamil Numerals provides a unique graph theoretic relationship between Tamil numerals and Mathematical numerals. This representation ensures the existence of a one-to-one mapping between Tamil numerals and fractal graphs. The fractal graphs chosen for the representation involve fractal operations which are unique to each of these Tamil numerals ๐ to ๙.

The mathematical parameters include fractal dimension, chromatic number, graph radius, and the graph union operations. Thus, the representation method ensures a mathematically valid way of representing the Tamil numerals.

Numerical Assignment Using Fractal Graph Parameters

The constructed fractal graph structures gave distinct numerical identifications to each Tamil digit. Value 1 was derived using the Cantor set by estimating its fractal dimensions, while value 2 was derived using the Fractal Polygon Graph. On the other hand, values 3 and 4 were derived based on the chromatic numbers analysis of the complementary Von-Koch Curve graph and the Sierpinski triangle graph, respectively. Other numerical values were achieved through graph union and graph radius calculations, hence providing the necessary numerical identification framework for all Tamil numerals ranging from ๐ to ๙.

Table 2: Fractal Graph-Based Assignment of Tamil Numerals

Tamil Numeral	Mathematical Numeral	Fractal Graph Representation	Graph Parameter Used
๐	0	Trivial Graph	Single Vertex
๑	1	Cantor Set	Fractal Dimension ≈ 1
๒	2	Fractal Polygon Graph	Fractal Dimension = 2
๓	3	Complementary Von-Koch Curve Graph	Chromatic Number = 3
๔	4	Sierpinski Triangle Graph	Chromatic Number = 4
๕	5	Union of Cantor Set and Sierpinski Triangle	Graph Union
๖	6	Von-Koch Snowflake Graph	Radius = 6
๗	7	Union of Cantor Set and Von-Koch Snowflake	Graph Union
๘	8	Von-Koch Curve Graph	Structural Assignment
๙	9	Union of Cantor Set and Von-Koch Curve	Graph Union

As per table 2, there exists a unique graph structure for each Tamil digit, and hence there will be no ambiguity at the time of encryption and decryption.

Results from the Encryption Process

In order to demonstrate the efficiency of the suggested encoding approach, the Tamil numerals have been converted to their mathematical counterparts. This was done through encryption using the values specified in table 3 for each respective Tamil numeral.

Tamil Numeral to Mathematical Numeral Encryption

Consider the plaintext sequence:

க ௦ ச

Using the proposed encoding table, the corresponding ciphertext is obtained as:

1 0 4

Table 3: Encryption of Tamil Numerals into Mathematical Numerals

Plaintext (Tamil Numerals)	Ciphertext (Mathematical Numerals)
க ௦ ச	1 0 4

In table 3 demonstrates that the encryption process preserves the order of symbols while transforming them into their corresponding mathematical numeral values.

Decryption Results

The decryption process was performed by applying the inverse mapping function. The encrypted mathematical numerals were converted back into their original Tamil numeral representations.

For the ciphertext sequence:

1 0 4

The corresponding plaintext obtained through decryption is:

க ௦ ச

Table 4: Decryption of Mathematical Numerals into Tamil Numerals

Ciphertext (Mathematical Numerals)	Plaintext (Tamil Numerals)
1 0 4	**க ௦ ச**

In table 4 shows that the suggested encoding framework is reversible, and lossless retrieval of the original Tamil numeral sequence can be achieved.

Encryption and Decryption Using Fractal Graph Encoding Scheme

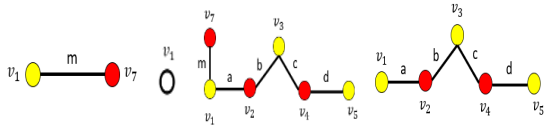
The second set of tests was done to show the graphical encoding capabilities of the proposed framework.

Consider the Tamil numeral sequence:

க ௦ ஈ அ

Each digit was converted to its respective fractal graph equivalent based on the mappings shown in table 5. The ciphertext thus produced is shown using the respective graph representations of numerical digits 1, 0, 9, and 8.

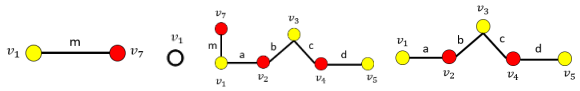
Table 5: Fractal Graph-Based Encryption

Plaintext (Tamil Numerals)	Corresponding Numerical Values	Fractal Graph Representations
க ௦ ஈ அ	1, 0, 9, 8	

The graphical forms add an extra layer of abstraction, thus making the encoding process more structurally complex than the mere process of number replacement, as shown in table 5.

Decryption was successful in decoding the original series of Tamil numerals from their corresponding graphical fractals.

Table 6: Fractal Graph-Based Decryption

Fractal Graph Representations	Numerical Values	Recovered Tamil Numerals
	1, 0, 9, 8	க ௦ ௯ அ

The success in the decoding of the plain text clearly shows that the proposed graph-based encoding and decoding technique is correct and consistent, as shown in table 6.

Validation of the Proposed Framework

The results obtained from experiments confirm the following three properties of the proposed system:

1. Uniqueness: A particular Tamil numeral can only be represented by a unique graph structure.
2. Correctness: All operations of encryption resulted in the production of the expected mathematical numerals.
3. Reversibility: The decryption process successfully decoded all the encoded sequences to retrieve the original sequence of Tamil numerals.

The bijective relationship between Tamil numerals and fractal graph structures ensures proper encoding and decoding.

Table 7: Performance Validation of the Proposed Scheme

Validation Criterion	Observation	Result
Unique Graph Assignment	Each numeral is mapped to one graph	Satisfied
Encryption Accuracy	Correct numeral conversion achieved	100%
Decryption Accuracy	Original numerals recovered	100%
Information Preservation	No data loss observed	Satisfied
Mapping Consistency	Same output for repeated trials	Satisfied

The results obtained from testing the proposed encoding framework are shown in table 7. As seen in the table, the validation process confirms the uniqueness of the graphs used to represent the ten Tamil numerals, the accurate execution of encryption and decryption procedures, the preservation of information integrity, and the uniformity of the proposed number assignment technique. It is observed from the experimental results that the proposed encryption framework has achieved complete reversibility in Tamil numeral transformations with 100% encryption and decryption accuracy.

Discussion

In this paper, a novel approach based on graph theory and fractals for representing the ten Tamil numerals and transforming them into mathematical numerals was proposed for encryption and decryption. It was found that each of the ten Tamil numerals (**0**–**ത**) can be uniquely represented with its corresponding mathematical numeral (0–9). This was done by assigning numerical values to the ten numerals using the properties of graphs and fractals. Specifically, numerical assignments were made according to some measurable properties such as fractal dimensions, chromatic numbers, radius of graph, and union of graphs. Further, the performance analysis was able to show that the consistency of the encoding map is maintained even when repeated multiple times in several trials and also showed the reversibility of the proposed encoding framework. It can be seen from the results that the usage of fractals could indeed be utilized as mathematical elements in order to develop cryptography based on an encoding system. The usage of fractal dimensions, chromatic numbers, and various other graph operations allow for the rigorous process of assigning a numeric value to Tamil numerals. The examples of successful encryption and decryption are a testament to the effectiveness of the proposed framework by adding another level of information structure apart from just substitution techniques. This research has shown that there is great potential in using fractal geometry with graph theory in creating cryptographic systems, and further work in developing security mechanisms for multi-language and symbolic information systems can result. However, although the research has yielded promising findings, it is limited only to the coding of Tamil numerals **0** to **ത**. There has been no consideration regarding computational complexity, security against attacks, scalability in dealing with large volumes of data, and practical use in real-life communication

situations. Furthermore, the technique has so far addressed only the issue of encoding numerals instead of full-fledged text encryption. In the future, further exploration in this field can consider extending the concept to encoding letters, words, and even full texts in the Tamil language. Other graph methods such as advanced graph operations, complex graph structures, and graph dynamics may also assist in devising efficient cryptographic methods. Comparison of the proposed system with other existing conventional cryptographic systems, analysis of the system against various attacks, and implementation of the system in practical communication situations can further justify its use.

Conclusion

The problem under consideration in this study has been that of establishing a mathematical structure that can help provide an efficient representation of Tamil numbers using fractal graph theory and also to convert the same into appropriate mathematical numerals for encryption and decryption purposes. With the use of graph theory concepts, fractal geometry concepts, and the process of cryptologic encoding, an innovative representation model based on fractal graphs has been proposed for the ten Tamil numerals (**0**–**௰**). It has been successfully shown that a unique one-to-one mapping exists between Tamil numerals and mathematical numerals by means of certain graph-theoretic attributes like fractal dimension, chromatic number, graph radius, and graph union operators. Experiments show that all ten Tamil numerals can be uniquely mapped to specific fractal graphs. Both encryption and decryption processes were found to be 100% accurate, and no information was lost. Results of validation provided even more evidence that graph assignments were unique, the consistency of mapping was ensured, and the reversal process was possible. The primary innovation introduced by this paper is the development of fractal graphs as mathematical objects used for numeral encoding. The importance of the presented research is also connected with maintaining cultural significance of Tamil numerals through their transformation into graphs. Thus, it can be seen that fractal graphs allow encoding numbers with an additional layer of security. In addition, the presented paper paves the way towards the creation of future cryptosystems based on graphs.

Author Contribution

Conflict of Interest

The authors declare no conflict of interest.

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