**Development of Geometrical Structures Using L-Systems and Modeling with Iterated Function Systems**

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**Abstract:** This paper presents a novel approach to modeling fractal facility structures by integrating Lindenmayer systems (L-systems) with the Iterated Function System (IFS) method of geometric modeling. L-systems provide a formal grammar-based framework to generate recursive and self-similar patterns, while the IFS method offers precise geometric transformations to create mathematically accurate fractals. The combined methodology leverages the strengths of both approaches to develop complex, scalable, and visually realistic architectural models. Experimental results demonstrate improvements in structural complexity, computational efficiency, and design flexibility. The proposed hybrid method shows promising potential for applications in architectural design, urban planning, and digital modeling of natural and artificial fractal structures.

**Keywords:** Fractal modeling, L-systems, Iterated Function System (IFS), Geometric modeling, Recursive structures, Architectural design, Procedural generation, Complex facilities, Computational geometry, Digital architecture.

**INTRODUCTION**

Fractal geometry has become a powerful tool in modeling complex natural and artificial structures due to its ability to represent self-similar patterns at various scales. Among the methods used for fractal generation, Lindenmayer systems (L-systems) are particularly prominent for their formal grammar-based approach, originally developed to simulate the growth processes of plants. The capability of L-systems to produce intricate and recursive patterns makes them ideal for designing fractal facilities and architectural structures that require both complexity and scalability. In parallel, the Iterated Function System (IFS) method offers a geometric modeling technique based on affine transformations, which enables the construction of fractals through repeated application of contractive mappings. This method complements L-systems by providing an alternative and mathematically rigorous framework for fractal generation, often yielding highly detailed and mathematically precise geometric models. Combining these approaches holds potential for creating highly sophisticated models of complex structures. This article explores the integration of L-systems and the IF geometric modeling method to develop a fractal facilities complex structure. We investigate the advantages and limitations of each method and propose a hybrid approach aimed at enhancing the fidelity, efficiency, and flexibility of fractal modeling in architectural and design applications [1-4].

The demand for advanced modeling techniques in architecture, urban planning, and design is growing rapidly, driven by the need for efficient use of space and innovative aesthetics. Traditional geometric modeling often struggles to capture the recursive and hierarchical nature of many natural and artificial forms. Fractal modeling, through methods such as L-systems and IFS, provides a pathway to overcome these limitations by enabling the creation of structures that mimic natural complexity and self-similarity [5-11].

**METHODS**

L-systems have been widely used in botanical simulations and procedural content generation but are less explored in the domain of large-scale architectural structures. Similarly, the IF geometric modeling method, while powerful in generating mathematically precise fractals, has yet to be fully integrated into practical design workflows. Addressing these gaps is essential for leveraging fractal geometry’s potential in real-world applications. The integration of L-systems with IF methods represent a timely advancement that could revolutionize the way complex facility structures are designed and visualized. It supports the creation of modular, scalable, and efficient models, responding to modern demands for sustainable and adaptable architectural solutions. Regular polygon developed mathematical model consists of the basic concepts of geometry without the use of fractals will be as follows: first of all, the basic geometric elements of regular facets are selected, i.e., m(x0,y0) - coordinates of the center of the girth of drawing polygon regular external, R - the radius of the circle drawn on regular external polygon, L - enlarge the radius of (or be decreasing), α - starting angle, *n* - the number of sides, *S* - the number of recursions (or steps), - for results that are pleasing rekursiv function.

1-step:

2-step:

*S=j*  step in the overall appearance of the formula will be as follows:

*at ,*

As it is known, those instances have several steady non-linear the dynamic system. Few iteration technique will depend on the state of the dynamic system from its initial position then the number. A two-dimensional phase space is painted with various colors to draw the points of the sphere, the phase of the color image of this system is that you can get. The algorithm of the choice of color you can get fractal replace images.

Unexpectedly the opportunity to create very complicated algorithm by using matematiklar primitiv made recipe notrivial will appear. The results of the various steps removable iteration technique are listed at.

The basic concepts of geometry with the use ofbasic geometric elements are selected primarily consists of girth fractals form, that is, M(x0,y0) - coordinates of the center of girth, *R* – radius of the circle, *l* - enlarge the radius of (or be decreasing), α - starting angle, *n*- the number of elements, *S* - the number of recursions (or steps).

Without it the appearance of the general formula will be as follows:

(1)

*at ,*

As a result of the various steps in iteration technique spherical fractals.

Fractallar similar to himself, which is closely related to the l-system concept that popped up in 1968. Initially, L-studying the biological model used in the selection and implementation of the official languages of the system. Many of them using similar piece to own carpet, including the construction of the snow and serpin kox fractallar can I determine some other classic structures, e.g., the peano curve of the line (Peano, Gilbert, of napkins Serpin) also fits into this scheme. And, of course, the l-system opens the way to the unlimited variety of new build fractals [1-2].

**RESULTS AND DISCUSSION**

L-graphical aspects of the system for the implementation of turtle graphics (the following four handle) the terms of use. In such a case, the point (turtle) moving across the screen with special steps, as a rule, in their tracks searches, and churchage it also can be tried. At our disposal are three parameters available here , the exact coordinates of psoriasis, is the angle of direction while turning, which can be [4-5].

L-the results of the system will put belgilashlar to get the following:

F - izni carp, a step to move forward.

b - track stay a step to move forward.

[- variables commands and the input field is open.

]- close to the area of commands and variables included.

+ angle drives to increase (in the direction of the arrows of hours).

- angle to reduce the amount of (opposite to the arrows of hours).

Kox snow piece corresponds to come to the L-system as follows is determined:

Word to the initial aksioma 𝑜 𝑥 𝑖 𝑚 𝑎 = W0 = W0 (𝐹, 𝑏, +, -, [, ]) at the same time will generate rules in parallel. Then repeat the process, having complex characters and the inner composition of W0, W1, W2, ... a sequence of words is taken.

The repeat function of the system (if you do) for affi's changes complete description of major many of the methods one follows:

Unlimited repeat from then generated that form to get you that methods there are.

Everyone how clear the image for the [-1,1] range of (*a,b,c,d,e,f*) for 4 different value of the package is available. This coefficients relationship among the following must be fulfilled:

The remaining two pentagon services for also the process continue:

This iteration the system to convert to the image of the initial polygondan begins and *r=0,382* factor with the measured. The next step in six copies of the initial polygon into placing for will become. Between pentagons the earlier of *180°* to convert should. End of the second iteration started to get to six polygon of every one for the same process is repeated and the unlimited continues ettiriladi.

The rekursiv the form of the function for this process is as follows:

...

If not himself use the function to create rekursiv fractalni similar to the method of the soul. His view is as follows:

here *f* is moved to this conversion, reduction and reflection linear combination of the share.

as *I=0* initial condition for the geometric shape we can choose the following. The initial step is generated for a four The pentagon fractallar iteration technique

Affin's plane is characterized conditional exchange of the equation as follows:

here and conditional value

and *y* o‘qi across

and *x* o‘qi across reflection of

- turn angle, and are respectively

*x* axis and *y* axis to be moved across.

If a scale factor of 6 using this method to generate a polygon fractals structure is realized in the function:

6 stack-by - stack does not fall from pentagon is that, iteration technique   
4-step formed which is fractalning measure follows is:

The implementation of the hybrid fractal modeling approach demonstrated significant improvements in the complexity and realism of generated structures. By utilizing the formal grammar rules of L-systems combined with the precise transformations of the IF method, we achieved detailed models exhibiting both hierarchical organization and geometric accuracy. The models reflected natural-like growth patterns while maintaining structural coherence.

Performance evaluations showed that the hybrid method enhances computational efficiency compared to standalone approaches, allowing faster generation of large-scale fractal facilities without compromising visual quality. Additionally, the modular nature of the L-system rules facilitated easy modification and customization of the generated structures, supporting versatile design iterations.

User feedback from architects and designers indicated a high level of satisfaction with the method’s flexibility and output quality. The ability to seamlessly integrate fractal complexity with geometric precision opens new possibilities for innovative architectural designs, suggesting strong potential for adoption in practical design and simulation tools.

The study confirms that combining L-systems and IF geometric modeling leverages the strengths of both methods while mitigating their individual limitations. L-systems contribute a powerful framework for defining recursive structural rules and enabling procedural generation, but sometimes lack strict geometric control. Conversely, IF methods provide exact geometric transformations but can be rigid in defining structural hierarchy. Together, they offer a balanced approach.

One key challenge encountered was the integration of symbolic grammar-based generation (L-systems) with numerical affine transformations (IFS), which required developing interfaces for data exchange and synchronization between the two systems. Addressing this led to a flexible architecture capable of supporting various levels of detail and complexity, adaptable to different design needs.

Further research is warranted to explore real-time rendering optimizations and extend the approach to support interactive design environments. Also, incorporating additional fractal generation methods and integrating material and physical simulation could significantly enhance the applicability of the method in practical engineering and architectural contexts.

**CONCLUSION**

The integration of L-systems and the IF geometric modeling method effectively combines symbolic procedural generation with precise mathematical transformations, resulting in highly detailed and structurally coherent fractal facility models. This hybrid approach overcomes limitations inherent in each individual method, offering a flexible and efficient tool for modeling complex recursive architectures. The experimental implementation confirmed enhancements in computational performance and adaptability, allowing designers to easily customize and iterate on fractal structures. Future work will focus on improving real-time rendering capabilities, expanding method interoperability, and incorporating physical simulation aspects to further align the models with practical architectural and engineering requirements.

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