2.5D Tree Model Tokenization for Smart Green Infrastructure: A voice-to-CAD AI chatbot for decentralized tree modeling

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Abstract: - Tree modeling architecture is regarded as the core element in smart green infrastructure (SGI) projects with great landscape spatial planning and forest monitoring functionality. A low-cost AI chatbot-based application prototype strategy was used to present and implement a novel, proof-of-concept, automated tree CAD modeling architecture with blockchain integration method. A tree CAD model made up of four 2D tree-frames forms the basis of the suggested parametric tree modeling methodology, with a demarcation between these frames at 45° (division angle), on which recorded tree-leaves color and texture have been assigned. A fully automated "Voice-to-CAD programming AI chatbot prototype" technique was employed, as a user-defined routine, at the top of an off-the-shelf CAD platform, to create tangible tree-model NFT tokens for building up an "Internet-of-Trees" thematic blockchain. In contrast to established methods based on diffusion models for tree growth simulation, the proposed "Blockchain/Merkle hash tree" tracks tree geometry growth and leaves texture change temporarily with simple parametric transactions (controlled Merkle hash tree scaling) and has great modification and redesign ability for SGI, forest, and pocket-park planning intelligence. This adds functionality and value to the CAD-blockchain integration industry.

Key-Words: - Smart green infrastructure, L-systems, tree modeling architecture, voice-to-CAD programming, AI chatbot, blockchain tokenization, decentralized tree modeling (DeTMo).

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1 Introduction

Tree modeling architecture offers advantages to smart green infrastructure (SGI), forest, and landscape spatial planning and design. Blockchain technology (BC), in this domain, enables collaborative engineering, data integrity, information confidence, and environmental data intelligence.

As a low-cost application study that impacts the digital landscape architecture design infrastructures and forest monitoring, a proof-of-concept automated tree modeling architecture and BC integration technique was given. A tree CAD model made from four 2D tree-frames with a 45° (division angle) demarcation between them, on which recorded tree texture has been allocated, forms the basis of the suggested parametric tree modeling technique.

To generate tangible tree-model NFT tokens for constructing a thematic Internet-of-Tree models (IoTr-models) blockchain, a fully automated "Voice-to-CAD programming" AI chatbot prototype technique has been implemented as a user-defined add-in software routine at the top of an off-the-shelf CAD platform. In this domain, the term "*decentralized tree modeling*" (DeTMo) is introduced, for the first time in literature, to describe the concept "*tree modeling: from shared knowledge to sustainable SGI value*".

When compared to conventional 3D tree modeling techniques (terrestrial, drone, and close-range photogrammetry, laser scanning, etc.), the add-in planning intelligence, the outstanding data integrity and confidence, the offline relaxed error-free CAD design, the superiority in terms of time and cost, and the satisfactory tree modeling accuracy and plain Merkle hash tree magnification for smart forest monitoring and landscape architecture applications were all noted as significant findings.

Because the core "Blockchain/Merkle hash tree" tracks tree geometry growth and texture change temporarily with straightforward parametric transactions (controlled hash tree magnification/scaling), the proposed parametric tree modeling architecture adds flexibility, functionality, and value to the comprehensive CAD-BC integration industry. It also supports metaverse functionality (same-data sharing; decentralized, parallel, and coordinated design; data validation; modification and redesign ability; scalable AI practicality; and planning intelligence). The primary contributions are thought to be distributed simulation, environmental data intelligence, and off-the-shelf smart forest surveillance.

The suggested method for parametric tree CAD modeling in relation to a *ground reference point* (GRP) for tree CAD geometry deployment (geo-referenced tree-CAD frames) makes use of speech-to-text batch commands and event-driven routines (such as design level/layer, weight, color, style, reference point, width, and height). As a result, the suggested method significantly lowers expenses, optimizes time, and enables the operation and upkeep of a straightforward and useful thematic blockchain with all that this entails at the level of distributed and cooperative design.

The suggested method undoubtedly generates less realistic tree CAD models; however this drawback has no bearing on applications related to SGI, smart forests, agriculture, or landscape architecture, [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Tree architecture modeling streams data analytics frameworks, hybrid learning, fraud concerns, and blockchain safety and opportunities challenges, [11], [12], [13], [14], [15].

The primary goal of the study is to provide an experimental method for incorporating tree-images into 2D CAD frames that are mutually perpendicular and linking them into a thematic blockchain specifically designed for IoTr models.

Thanks to a scalable and relatively straightforward "Merkle hash tree" that temporarily tracks tree geometry growth and texture change using plain parametric transactions of generic tangible tree-model NFTs, the suggested tree model adds new value and environmental intelligence to the CAD-BC integration market, [4], [16], [17], [18], [19].

The notable significance of this study lies in the simple, transparent, and plain "Blockchain/Merkle hash tree" structure supporting collaborative and distributed tree architecture for monitoring landscape architecture, environmental intelligence, smart forest, VR, and digital documentation applications where there are no requirements on the accuracy of the tree representation, [9], [10], [20], [21], [22], [23], [24, [25], [26].

The remainder of the paper is structured as follows. In "Related Work," (Section 2), published knowledge about sketch-based synthetic trees, diffusion models for growth simulation, text-to-3D tree models' generation, and CAD-BC integration, spatial analysis, and tree visualization is discussed. In Section 3 ("Method and Tools"), the proposed off-the-shelf "*Voice-to-CAD programming AI chatbot prototype*" technique and its "*Tree CAD programming: The adverbs-verb-nouns metaphor*" implementation are introduced. A tree CAD modeling case study and the conceptual IoTr-models theme blockchain outline design (experimental approach) are described in Section 4 ("Experiments"), which is followed by a qualitative and quantitative comparison analysis as an IoTr-models evaluation test. Lastly, the article's main conclusions, findings, relevance, contributions, limitations, and recommendations for additional research are covered in Section 5 ("Discussion and Conclusions").

2 Related Work

According to [27], [28], [29], [30], and [31], the established techniques for dynamic plant and tree 3D geometry growth simulation and controllable text-to-3D generation are based on L-systems with diffusion-guided Gaussian splatting models.

Particularly:

Sketch-based synthetic trees. Data scarcity is a barrier in many plant phenotyping problems [32], and synthetic data can be used to replace or supplement real data for downstream models, as recent research has increasingly shown [33], [34]. Numerous methods have been used to create synthetic plants. Using their photorealism for 2D images, generative methods such as GANs (generative adversarial networks, [35]) and diffusion models, [36], as leading generative AI techniques, have produced images for training phenotyping AI [37]. Although they offer a foundation for the creation of complex biological structures, structural plant modeling techniques - most notably L-systems [38]- must be combined with other CAD modeling techniques to generate photorealistic 3D models.

To obtain precise geometry and detailed control over picture content, recent efforts, [30], [31] combine image-to-image generative AI with 3D morphological modeling techniques. However, because of the intricate structures of plants and substantial opacity from any one perspective, 2D phenotyping has severe limits, and the CAD-BC integration for a thematic IoTr-models framework remains complicated and not scalable.

Using GANs to learn the mapping between sketches and photos is one popular method. Recent publications [39], [40] use pre-trained T2I models for sketch-based visual synthesis. These models use the sketch to direct the diffusion model when given a text prompt and a sketch, producing results that match the spatial arrangement of the sketch and the text query.

We go one step further in this paper by demonstrating sketch controlling in the context of voice-to-text-to-2.5D CAD production for the first time. We see that Sketch2Mesh [41] is a similar work that concentrates on 3D modeling generation from sketches. Our study, however, focuses on producing plain 2.5D scenarios that are conditioned on both a visual signal (four raster images) and a written chatbot prompt, which is more flexible, offering great CAD-BC integration scalability.

Diffusion models for growth simulation. The newest trend in generative models for producing varied, excellent content is diffusion models, [42]. Particularly, they have recently been utilized to create cutting-edge text-to-image (T2I) models (such as Imagen, [43]) with the aid of extensive datasets. When the user provides a natural language text cue, these models may produce high-quality photographs of items and scenes.

Many studies try to guide pre-trained text-to-image (T2I) diffusion models to support additional input conditions, driven by the success of these models. A recent study called ControlNet, [40] suggests using additional condition inputs, such as edge maps, segmentation maps, drawings, etc., to regulate the large image diffusion model (also known as Stable Diffusion). According to [40], [42], and [43], using text prompts (as AI chatbots) and condition raster imagery to describe and regulate 3D tree generation is still an open and difficult subject not suitable for thematic IoTr-models blockchains, despite advancements in programmable 2D T2I generation.

Text-to-3D tree models' generation. According to [42] and [43], multimedia content creation has advanced significantly in recent years. In the interim, there has been an increase in interest in text-to-3D modeling due to recent significant developments in T2I generation and NeRF-based 3D reconstruction, [40], [43]. For the construction of T2I, extensive paired text-image data is provided, but comparable-scale paired text-3D data are not yet accessible. PlantDreamer, [30] optimizes underlying 3D representations by utilizing cross-modal knowledge and pre-trained T2I diffusion in 2D image generation for text-to-3D synthesis. In this way, the requirement for training data is eliminated, but, nevertheless, the 3D output is typically less lifelike.

Using both low- and high-resolution diffusion priors in a coarse-to-fine method, Control3D, [31] significantly enhances the text-to-3D generation quality and controllability for users that correspond to the input text prompt. Nevertheless, Control3D and similar techniques are unable to use additional freehand interfaces to manage the 3D generation process. Instead, we address a new and difficult topic in this paper: using a simple voice-to-CAD programming AI chatbot prototype to guide the voice-to-text-to-2.5D process.

Nevertheless, the 3D mesh is extremely complicated and challenging for most CAD end-users to create. On the other hand, our suggested technique, based on four orthogonal CAD frames which are shown as a sketch, is easier to understand and utilize plain and scalable "Merkle hash tree" structures for thematic IoTr-models BC. The most relevant studies, but without an AI chatbot utility, that use plain orthogonal CAD frames and raster tree images to direct the tree modeling creation process are, [10] and [23].

CAD-Blockchain integration, spatial analysis, and tree visualization. In [14], [15], and [44], the authors proclaim that a smart urban transformation requires tree visualization data, and according to [9], [10], and [45], tree geometry is essential for GIS (spatial) analysis for forest, landscape architecture, and pocket parks projects. Data integrity, collaborative, distributed, and verified digital design are supported by BC in intelligent CAD projects, according to [12], [13], and [14]. Additionally, a scalable digital design requires a CAD-BC integration strategy, according to [46], [47], and [48]. The "collaborative tree design-blockchain integration" issue is thoroughly covered in this literature, but no low-cost integration solution is mentioned.

Similar to this, the authors of [25], [49], and [50] talk about data for structural monitoring in asynchronous communication, while the authors of [5], [6], and [7] talk about how BC adoption affects smart city intelligence and the building information modeling (BIM) process without mentioning trees as the fundamental representation core element of a green-oriented urban environment.

The current study claims that tracking tree texture change and monitoring 3D tree shape growth in almost real-time is an ideal off-the-shelf distributed and collaborative environment, but it requires time, money, expertise, intelligence, and a challenging "Blockchain/Merkle hash tree."

In [8], [51], and [52], the authors describe in detail methods for linking digital twins and assets (environmental data simulation) to a 3D model for structural monitoring, assessment of visual landscape quality, and urban adaptive transformation, but no information is given about a potential Blockchain integration for environmental data (tree) intelligence.

Lastly, taxonomy and ontology-based approaches, distributed platforms, operation management, and decision-support models for sustainable urban investment optimization may be helpful in urban transformation processes, according to [13], [53], [54], [55], and [56]. However, no implementation details for collaborative, intelligent, and distributed environments are provided.

3 Method and Tools

Nowadays, text-by-voice techniques use AI cloud APIs, driven by high-tech giants like Google, to accurately translate speech into text.

3.1 The voice-to-CAD programming AI chatbot prototype

In the proposed tree modeling-tokenization framework for SGI with CAD-BC integration functionality, facilitated by a personalized pull-down menu, the voice-to-CAD programming segment uses Google's speech-to-text Python API to generate customized key-in CAD intelligence that is embedded in a simple (ASCII) text file and displayed in an AI chatbot dialog, enhancing transparency and provability (the state or quality of being logically demonstrable or provable) to CAD programming assets. Following this, this key-in CAD intelligence initiates specific event-driven CAD routines for tree modeling, setting up a tree-model NFT wallet, creating tangible tokens, and adding to the thematic personalized "IoTr-models" BC.

Figure 1 displays the personalized pull-down menu "Smart Green Infrastructure/my AI Chatbot; Tree CAD modeling; BC Tokenization".

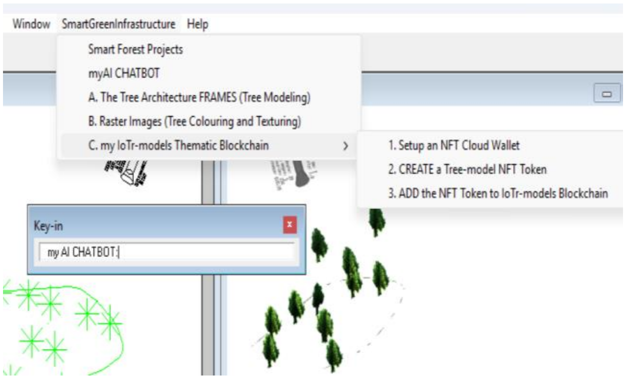


Fig. 1: The "SGI/chatbot; modeling; tokenization" pull-down menu. *Source: created by the authors*

Particularly, our technique converts simple English speech notes such as "Place Point", "Place Block", "Rotate", "Assign Image", "Attach Texture", "Setup NFT Wallet", "Create NFT Token", and "Add NFT Token to my-Blockchain", into relative text sequences displayed on an AI chatbot prototype dialog ("Ctlr-Shift" triggering), and following tokenizing relative CAD commands, as digital assets, for CAD programming and tree modeling (Figure 2).

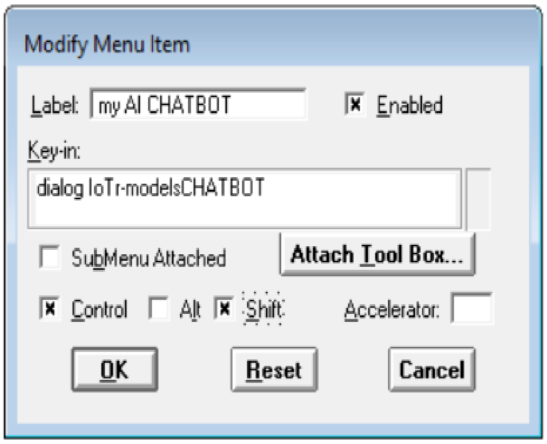
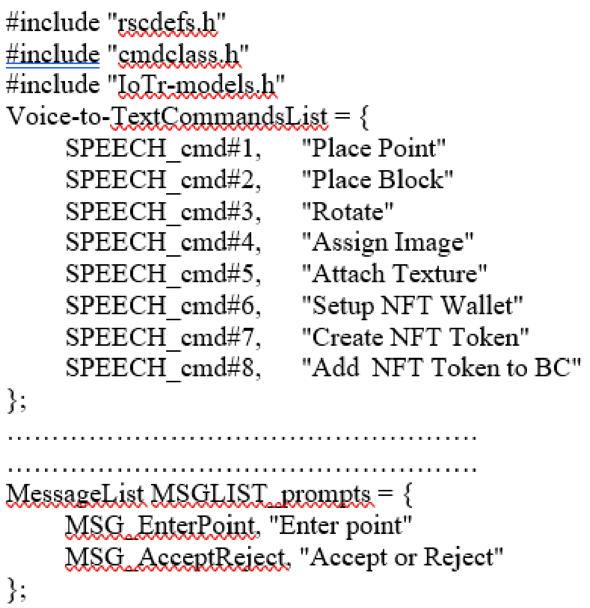


Fig. 2: The "my AI Chatbot" dialog. *Source: created by the authors and MicroStation® CAD software*

This vector parametric modeling technique offers great CAD flexibility (geometric transformations like tree model "move", "rotate", "mirror", "scale", etc.), excellent tree modeling functionality (tree dimensions, color, and texture), and impressive support for a scalable "IoTr-models" BC with plain tree model NFT tokens. This removes the requirement for a costly (in terms of time, money, and resources) point-by-point design in CAD tree modeling architecture.

It is important to emphasize that, even though existing software such as real-time 3D tree modeling generators like "Tree It", [57] and CAD software platforms like Bentley's MicroStation and Autodesk's AutoCAD, [1], [9], [10], [58], [59], does not support CAD-BC integration, our approach has developed a code in MDL ("MicroStation Development Language" / a low-level C-like CAD-oriented language for event-driven drafting, design, and modeling add-in intelligence), on top of the conventional computer-aided design environment that supports "voice-to-CAD programming" tree modeling and BC tokenization (Figure 3).



```
#include "rscdefs.h"
#include "cmdclass.h"
#include "IoTr-models.h"
Voice-to-TextCommandsList = {
        SPEECH_cmd#1,    "Place Point"
        SPEECH_cmd#2,    "Place Block"
        SPEECH_cmd#3,    "Rotate"
        SPEECH_cmd#4,    "Assign Image"
        SPEECH_cmd#5,    "Attach Texture"
        SPEECH_cmd#6,    "Setup NFT Wallet"
        SPEECH_cmd#7,    "Create NFT Token"
        SPEECH_cmd#8,    "Add  NFT Token to BC"
};
……………………………………………
……………………………………………
MessageList MSGLIST_prompts = {
        MSG_EnterPoint, "Enter point"
        MSG_AcceptReject, "Accept or Reject"
};
```

Fig. 3: MDL code fragment. *Source: created by the authors*

For generic 2.5D tree modeling, our approach is based on a relative design of four rectangular CAD tree-frames that are perpendicular to each other. A *ground reference point* (GRP) with coordinates 0,0,0 (i.e., a local datum for an intelligent relative-to-GRP tree modeling deployment) is geo-referencing this tree-frames architecture (Figure 4).

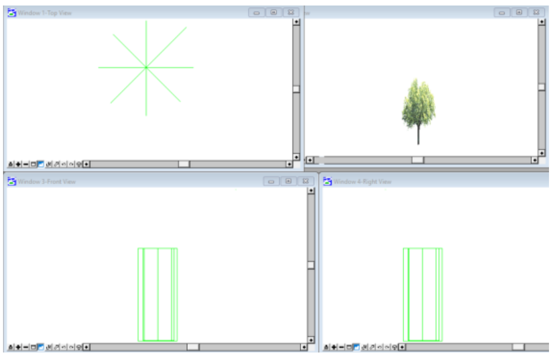


Fig. 4: The perpendicularly-centered four orthogonal tree CAD frames (views: TOP, FRONT, RIGHT, ISOmetric). *Source: created by the authors*

The next step is to assign inexpensive tree photography (e.g., jpg images from smartphones) to these frames so they can be used as tree imaging and texturing. Following, the so-called "IoTr-models" dedicated blockchain stores this general tree format as a concrete tree-model NFT digital asset/token (tree CAD model tokenization). The first phase of a ten-tree smart forest application (a multi-tree modeling architecture) is shown in Figure 5.

This multi-tree modeling is common in SGI projects and is supported by a pull-down option in the main menu's "Smart Green Infrastructure" item (see Fig. 1).

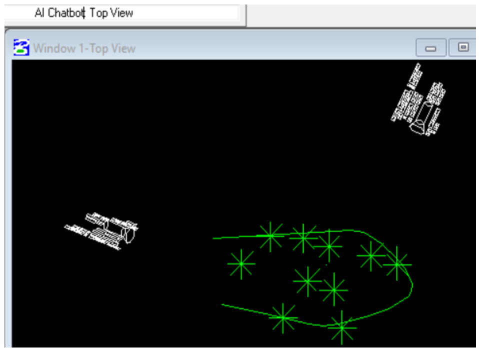


Fig. 5: The ten (10) perpendicularly-centered compound orthogonal tree CAD frames for a smart forest application (view: TOP). *Source: created by the authors*

For visualization and digital documentation projects pertaining to tree landscapes, forests, monument landscapes rich in trees, and various landscape architecture applications, the modeling and visualization accuracy of the suggested 2.5D tree CAD modeling framework is satisfactory, sufficient, and acceptable for environmental intelligence without exceptional tree-shape modeling and visualization requirements.

3.2 Tree CAD programming: The adverbs-verb-nouns metaphor

To employ AI user-CAD communication functionality, like oral and written conceptual metaphors in human communication, we are introducing an "*adverbs-verb-nouns*" CAD programming metaphor.

Hence, the system CAD variables level (LV), color (CO), weight (WT), and style (LC) are engaged as "*adverbs*" parameters in the proposed 2.5D CAD modeling process. Following, several commands (Place Point, Place Block, Rotate, Assign, Attach, Setup, Create, Add) are operated as "*verb*" functions. Finally, the frame's georeferencing point X, Y, and Z coordinates (GRP), the tree's height (Height) and widths (Width1, Width2), and the raster images (Image1, Image2) for the color and the texture of the tree leaves utilize the "nouns" part of the introduced metaphor.

At the heart of the AI chatbot prototype, as our CAD "*adverbs-verb-nouns*" programming implementation technique, is an ASCII batch text file (e.g., "*TreeModeling-Tokenization.bat*") produced by the AI chatbot (with the "copy myAIchatbot FileName" function) and located at the periphery of the host CAD platform. This ASCII file is suitable for sequential top-down CAD programming (Figure 6).

```
//  2.5D Tree CAD Model Tokenization for Smart Green Infrastructure
// A Voice-to-CAD Programming AI Chatbot Prototype
// TreeModeling-Tokenization.bat: The ASCII batch text file with CAD key-in commands
// produced by the AI chatbot following an "adverbs-verb-nouns" programming technique
// © 2026 - D. Varveris, P. Xofis, V. Basdekidou
Xorigin = GPS X coordinate; Yorigin = GPS Y coordinate; Zorigin = GPS Z coordinate
        // CAD Programming Routine
mySmart2.5DTreeCADModel-Tokenization (Xorigin, Yorigin, Zorigin, Width1, Width2,
Height, Image1, Image2, Image3, Image4, Tree-Leaves-Texture, Tree-Leaves-Color) {
        LV=0; CO=20; LC=0; WT=3  // The Adverbs
        Place Point              // The Verb
        XYZ=0, 0, 0              // The Nouns
        LV=10; CO=34; WT=0       // The Adverbs
        Place Block              // The Verb
        XYZ=Xorigin, Yorigin, Zorigin // The Nouns (flatbed plotter's referencing metaphor)
        DL=Width1,0,Height       // The Nouns for the #1 CAD tree-frame
        Copy-Rotate              // The Verb for the #3 CAD tree-frame
        Angle=45°                // The Noun
        XYZ=Xorigin, Yorigin, Zorigin // The Nouns (flatbed plotter's referencing metaphor)
        DL=0,Width2,Height       // The Nouns for the #2 CAD tree-frame
        Copy-Rotate              // The Verb for the #4 CAD tree-frame
        Angle=45°                // The Noun
                // Tree Imagery assignment from smart phone photography (jpg)
        ASSIGN Image1; ASSIGN Image2; ASSIGN Image3; ASSIGN Image4
                // Tree Texture attachment
        ATTACH Tree-Leaves-Texture; ATTACH Tree-Leaves-Color
                // Architectural lighting (global/source/solar)
        Setup Global-lighting; Setup Source-lighting
        Setup Solar-lighting (GPS X,Y,Z coordinates; Universal Time Zone)
                // Metaverse fly-through functionality
        Setup Fly-through
                //Tree-Tangible NFT ("Internet-of-Tree models" Blockchain)
            // The Cloud Wallet setup
        SETUP 2.5DTreeCADModel NFT Cloud Wallet
            //Tokenization (2.5TreeCADModel protection & a hash guaranteed uniqueness
        CREATE Tangible 2.5DTreeCADModel NFT Token
            // Thematic "Internet-of-Tees models" Blockchain updating (NFT Token)
        ADD Tangible 2.5DTreeCADModel NFT Token to "IoTr-models" Blockchain
}
```

Fig. 6: (*TreeModeling-Tokenization.bat)* The ASCII batch text file with CAD key-in commands produced by the AI chatbot following an "*adverbs-verb-nouns*" programming technique. *Source: created by the authors*

As an alternative to an AI chatbot prototype, the ASCII command file for the 2.5D tree CAD modeling and "IoTr-models" tokenization can be executed from a CAD software platform prompt (i.e., a key-in dialog box) by typing a link-string. For instance,

@c://SGI/TreeModeling-Tokenization.bat

The low-cost CAD platform MicroStation® (Bentley Systems, Inc.) -because of its adaptivity, usability, and thematic customization functionality- was used as the hosting software environment for the AI chatbot prototype implementation, the event-driven CAD procedures, and the command-line programming of the proposed framework.

The introduced novel "Smart Green Infrastructure with IoTr-models Blockchain" method, implemented by the "Voice-to-CAD programming AI Chatbot prototype" technique, is a "*smart modeling and tokenization*" Web3 (decentralized web built on blockchain technology) application because it operates with planning intelligence with Internet of Things (IoT) efficiency in real-time, while utilizing simple phrases from the English language.

Even more, it is flexible because it can be performed offline in a safe, relaxed, and friendly way, as an ASCII batch file with "verbs" obsessed with domain-dependent CAD functions, [1], [6], [9], [10], [29], [30], [31].

4 Experiments

The proposed method for SGI and its implementation chatbot technique has been assessed by a 2.5D tree CAD modeling with BC tokenization case study. The Section is completed with performance comparison and analysis for the proposed method's validation.

4.1 2.5D tree CAD modeling – Case study

Figure 7 demonstrates the proposed method's rendering functionality. Tree architecture lighting has been added for real-world appearance.

Fig. 7: Smart forest with architectural lighting (three digital cameras in Isometric view) *Source: created by the authors*

Furthermore, Figures 8 and Figure 9 demonstrate the method's acceptable tree modeling for environmental data intelligence, forest monitoring, and landscape architecture (e.g., pocket parks).

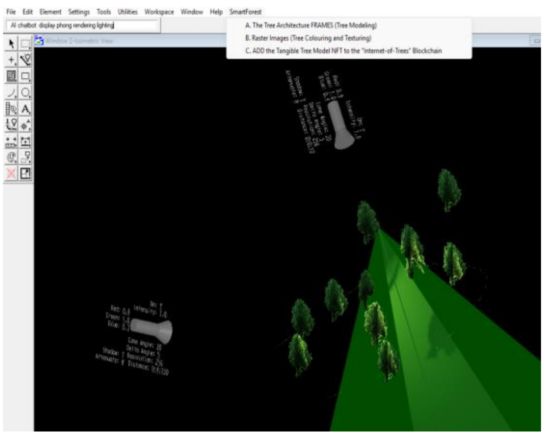


Fig. 8: 2.5D tree CAD modeling – A night view for a landscape architecture project (pocket park). *Source: created by the authors*

Fig. 9: 2.5D tree CAD modeling – A photorealistic view for a landscape architecture pocket park.
Source: created by the authors

4.2 "Internet-of-Tree Models" blockchain: The outline design

Figure 10 shows the 2.5D tree CAD model tokenization's outline design. A hash value generated by the SHA256 cryptographic technique is used to identify each 2.5D tree model as a block in the IoTr-models chain, [9], [10].

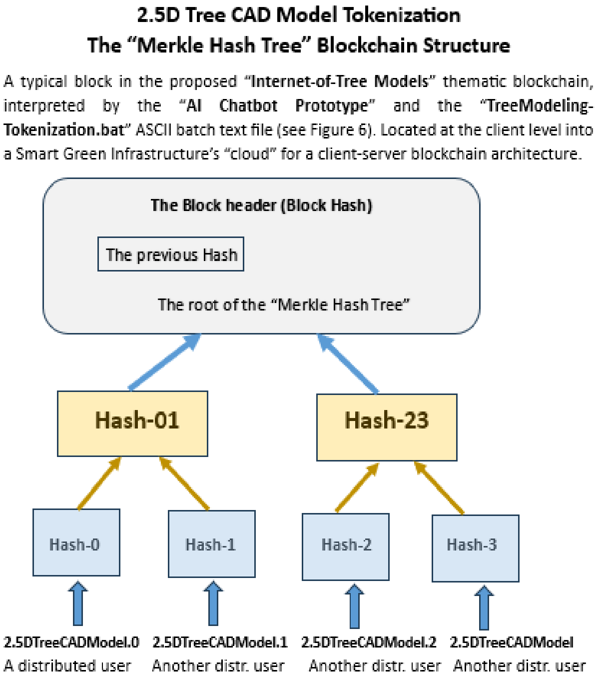


Fig. 10: 2.5D Tree CAD Model Tokenization: The "Merkle hash tree" blockchain structure. *Source: created by the authors*

Many 2.5D Tree CAD Models are provided as transactions by distributed users in a collaborative design environment and they are tokenized -hashed in the proposed "Merkle Hash Tree"- for Smart Green Infrastructure and Smart Forest projects.

Hence, the "IoTr-models" thematic blockchain is composed of a linked list of blocks of transactions tracking tree geometry growth and temporal texture change, [49], [60], [61]. The "Root of Hash Tree" points to a "Merkle hash tree" chain of transactions, [23] (Fig. 10).

It is crucial to understand that the "Merkle hash tree" in the tree CAD modeling tokenization (see Fig. 10) is comparatively plain, simple, compact in its extension, manageable, and scalable (i.e., supports a controlled magnification), [1], [9], [13], [48].

For rich-in-trees green infrastructures, urban parks, and forests, the IoTr-model "Merkle hash tree" is built using a bottom-up methodology. As a result, each leaf node (the Hash-0, Hash-1, Hash-2, and Hash-3 in Fig. 10) is a hash of transactional data, which includes the color (tree-leaves coloring) and texture (tree-leaves texturing) modification of the leaves, as well as the periodically recorded tree geometry growth (i.e., the tree dimensions). Additionally, the hash of its prior hashes is the non-leaf node (Hash-01 and Hash-23 in Fig. 10).

The proposed "Merkle hash tree" blockchain structure is a binary one; hence, it always needs an even number of leaf nodes.

Hash-01 = hash (Hash-0 & Hash-1)
Hash-23 = hash (Hash-2 & Hash-3)

Notes

1. The hash function SHA256 (a cryptographic technique) has been used for the hashing (hash values Hash-0, Hash-1, Hash-2, Hash-3, Hash-01, and Hash-23).

2. The first block in "IoTr-models" tokenization, known as "Block 0" or the "genesis block," served as the basis for the other blocks in the proposed chain. The "IoTr-models" thematic blockchain (tree-model NFT tokens ledger) begins with this block, also referred to as the basic block.

4.3 Evaluation

We conducted a comparative evaluation of our "Voice-to-2.5D tree CAD modeling" framework and two "text-to-3D generation" methods suitable for tree modeling (*PlantDreamer*, [30] and *Control3D*, [31]).

Our evaluation was focused on four key aspects:
(i) the tree modeling quality in terms of 3D geometry accuracy and texture fidelity (qualitative assessment),
(ii) the faithfulness and loyalty of the visual appearance, and the alignment and consistency of the tree modeling when initialized with real-world point "clouds" compared to the captured ground-truth (qualitative assessment),
(iii) the blockchain tokenization functionality in terms of "Merkle hash tree" structure and scalability (quantitative assessment), and
(iv) the tree modeling computational time (approx. in minutes) (quantitative assessment).

4.3.1 Qualitative comparison and analysis

The qualitative contrasts are shown in Figure 11. As shown in this figure, *PlantDreamer* and *Control3D* show much better tree modeling quality in terms of 3D geometry accuracy and texture fidelity. The faithfulness and loyalty of the visual appearance, and the alignment and consistency of the 3D tree model is great.

The 2.5D DeTMo framework, on the other hand, struggles to produce accurate and realistic 3D textures, which results in false visual appearances, even if it can produce 2.5D trees with a substantial and decent appearance.

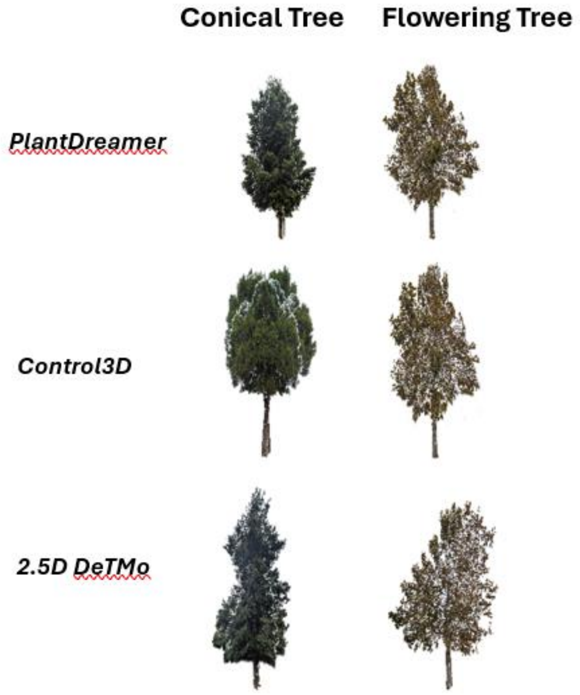


Fig. 11: Qualitative comparisons on text-to-3D generation *Source: created by the authors*

4.3.2 Quantitative comparison and analysis

Additionally, we carried out a bibliography-based study to quantitatively evaluate the "2.5D tree CAD model tokenization" framework against the two text-to-3D tree models generation methods.

Sacrificing 3D modeling accuracy, fidelity, and consistency for simplicity, our evaluation criteria, for quantitative comparison, are referred to computational time as it taken from bibliography referred to computational performance (see *PlantDreamer*, [30] for approx. 30 min run time, p.7; and *Control3D*, [31] for approx. 60 min training time, p.1152) and to tree model tokenization (Merkle hash tree's structure and scalability) because we do believe that decentralized tree modeling (DeTMo) is the future.

Table 1 presents the results of the quantitative comparison.

Table 1. Quantitative comparison

	(Tree model tokenization) Merkle Hash Tree		**Computational time**
	Structure	**Scalability**	**(approx. in min)**
PlantDreamer	Complicated	Limited	30 min, [30]
Control3D	Complicated	Limited	60 min, [31]
2.5D DeTMo	Plain	Excellent	25 min

Source: Created by the authors

In general, our "2.5D tree CAD model tokenization" framework, in terms of DeTMo tokenization and computational time, significantly outperforms the other two text-to-3D model methods with plain "Merkle has tree" structure, excellent blockchain scalability, and shorter computational time.

5 Discussion and Conclusions

Results and Findings. *Tree modeling quality*: The proposed 2.5D tree CAD modeling framework provides reasonable visual appearance and functionality for smart green infrastructure (SGI) projects, forest monitoring, and landscape architecture applications. However, it sacrifices 3D modeling accuracy and texture fidelity compared to advanced text-to-3D generation methods like PlantDreamer and Control3D. *Blockchain tokenization*: The framework introduces a plain and scalable "Merkle hash tree" structure for tree model tokenization. This structure is compact, manageable, and supports decentralized tree modeling (DeTMo) for collaborative design environments. *Computational efficiency*: The 2.5D tree CAD modeling framework demonstrates superior computational efficiency, completing tasks in approximately 25 minutes compared to 30 minutes for PlantDreamer and 60 minutes for Control3D.

Contributions and Significance. *Innovative voice-to-CAD programming*: The study introduces a novel AI chatbot prototype that converts voice commands into CAD programming instructions, enabling efficient and user-friendly tree modeling and blockchain tokenization. *Decentralized tree modeling (DeTMo)*: The framework supports the creation of a thematic "Internet-of-Trees" BC, enabling collaborative and distributed tree modeling for SGI and smart forest projects. *Low-cost solution*: The framework is implemented on an off-the-rack CAD platform (MicroStation®), making it accessible, practical, efficient, and affordable compared to expensive commercial 3D modeling methods. *Scalability*: The plain "Merkle hash tree" structure ensures excellent scalability for blockchain-based tree model tokenization, making it suitable for large-scale SGI projects.

Limitations. *Modeling accuracy*: The 2.5D tree CAD modeling framework produces less accurate and less realistic tree models compared to advanced 3D modeling techniques. *Texture fidelity*: The framework struggles with generating precise and lifelike textures, which may limit its application in projects requiring high visual accuracy. *Limited real-world testing*: The study primarily focuses on proof-of-concept and experimental validation, with limited real-world implementation.

Suggestions for Improvements and Further Study. *Enhancing texture fidelity*: Future studies could examine cutting-edge generative or agentic AI techniques, such as GANs or diffusion models, to improve texture realism. *Expanding real-world applications*: Conducting field tests in diverse SGI and forest monitoring projects to validate the framework's practical utility and scalability. *Integration with other CAD platforms*: Extending the framework to support other CAD platforms, such as AutoCAD, to increase accessibility and adoption. *Improving 3D modeling accuracy*: Investigating methods to enhance the accuracy of tree geometry and 3D modeling while maintaining computational efficiency.

Conclusions. The study presents a novel and cost-effective "Voice-to-CAD programming AI chatbot prototype" for 2.5D tree modeling and blockchain tokenization. The framework has limitations in terms of modeling accuracy and texture fidelity, despite its many benefits in terms of computational efficiency, tokenization scalability, and collaborative design. The proposed method is particularly suitable for SGI, smart forest monitoring, and landscape architecture applications where high precision is not critical. Future research should focus on improving texture realism, expanding real-world applications, and enhancing 3D modeling accuracy to broaden the framework's applicability and impact.

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References:

[1] Fortes, S., Hidalgo-Triana, N., Sánchez-la-Chica, J.-M., García-Ceballos, M.-L., Cantizani-Estepa, J., Pérez-Latorre, A.-V., Baena, E., Pineda, A., Barrios-Corpa, J., García-Marín, A. Smart Tree: An Architectural, Greening and ICT Multidisciplinary Approach to Smart Campus Environments. Sensors 2021, 21(21), 7202, https://doi.org/10.3390/s21217202

[2] Lin, W., Huang, X., Fang, H., Wang, V., Hua, Y., Wang, J., Yin, H., Yi, D., Yau, L. Blockchain Technology in Current Agricultural Systems: From Techniques to Applications. IEEE Access 2020, 8, 143920-143937, https://doi.org/10.1109/ACCESS.2020.3014522

[3] Xiong, H., Dalhaus, T., Wang, P., Huang, J. Blockchain Technology for Agriculture: Applications and Rationale. Front. Blockchain 2020, 3(7), https://doi.org/10.3389/fbloc.2020.00007

[4] Basdekidou, V., Papapanagos, H. Blockchain Technology Adoption for Agriculture, Manufacturing, Services, Knowledge, Culture, and Research: A Systematic Literature Review. WSEAS Transactions on Systems 2025, 24, 229-278, https://doi.org/10.37394/23202.2025.24.23

[5] Sadri, H., Yitmen, I., Tagliabue, L.C., Westphal, F., Tezel, A., Taheri, A., Sibenik, G.J.S. Integration of blockchain and digital twins in the smart built environment adopting disruptive technologies-A systematic review. Sustainability 2023, 15(4), 3713, https://doi.org/10.3390/su15043713

[6] Hellenborn, B., Eliasson, O., Yitmen, I., Sadri, H. Asset information requirements for blockchain-based digital twins: a data-driven predictive analytics perspective. Smart and Sustainable Built Environment 2023, 13 (1), 22-41, https://doi.org/10.1108/SASBE-08-2022-0183

[7] Rahman, A., Khan, M., Attom, B., Manoharan, M. Advanced Data Analytics in Green Finance: Blockchain and Digital Twin Integration. IGI Global 2024, https://doi.org/10.4018/979-8-3693-1878-2.ch010

[8] Farghally, H.M., Sweelem, E.A., Abu El-Sebah, M.I., Syam, F.A. Agricultural Grid Connected Photovoltaic System Design and Simulation in Egypt by using PVSYST Software. WSEAS Transactions on Circuits and Systems 2022, 21, 306-315, https://doi.org/10.37394/23201.2022.21.33

[9] Chen, C., Wang, H., Wang, D., Wang, D. Towards the digital twin of urban forest: 3D modeling and parameterization of large-scale

urban trees from close-range laser scanning. International Journal of Applied Earth Observation and Geoinformation 2024, 127, 103695, https://doi.org/10.1016/j.jag.2024.103695

[10] Wang, H., Wang, D. 3D semantic understanding of large-scale urban scenes from LiDAR point clouds. In: 2023 9th International Conference on Virtual Reality. ICVR 2023, 86–92, https://doi.org/10.1109/ICVR57957.2023.10169715 (Accessed Date: February, 20, 2026)

[11] Pesqueira, A., Sousa, M.J., Machado, A. de B. Addressing Counterfeiting and Fraud Concerns in Healthcare Packaging and Labeling with Blockchain: Opportunities and Challenges. WSEAS Transactions on Information Science and Applications 2024, 21, 246-263, https://doi.org/10.37394/23209.2024.21.24

[12] Andrae, A.S.G. Method for Calculating the Avoided Impact of Specific Information and Communication Technology Services. WSEAS Transactions on International Journal of Environmental Engineering and Development 2024, 2, 73-87, https://doi.org/10.37394/232033.2024.2.7

[13] Giannaris, P.S., Mastorakis, N.E. Overview of Taxonomy and Ontology Approaches for the Classification of Blockchain Components. WSEAS Transactions on Computer Research 2023, 11, 33-56, https://doi.org/10.37394/232018.2023.11.4

[14] Basdekidou, V., Papapanagos, H. Blockchain Technology Adoption for Disrupting FinTech Functionalities: A Systematic Literature Review for Corporate Management, Supply Chain, Banking Industry, and Stock Markets. Digital 2024, 4, 762-803, https://doi.org/10.3390/digital4030039

[15] Basdekidou, V.A., Papapanagos, H. Empirical Model for Estimating Sustainable Entrepreneurship's Growth Potential and Positive Outlook. Balt. J. Mod. Comput. 2023, 11, 181-201, https://doi.org/10.22364/bjmc.2023.11.1.11

[16] Habib, G., Sharma, S., Ibrahim, S., Ahmad, I., Qureshi, S., Ishfaq, M. Blockchain Technology: Benefits, Challenges, Applications, and Integration of Blockchain Technology with Cloud Computing. Future Internet 2022, 14, 341, https://doi.org/10.3390/fi14110341

[17] Mahmoud, M.S. Complete Results on Control and Filtering of Discrete Systems with Time Scales. WSEAS Transactions on Systems, 2019, 18, 319-329, Art. #40, www.wseas.com/journals/articles.php?id=1549 (Accessed Date: February, 22, 2026)

[18] Basdekidou, V., Papapanagos, H. The impact of FinTech/Blockchain adoption on corporate ESG and DEI performance. WSEAS Transactions on Business and Economics 2024, 21, 2145-2157, https://doi.org/10.37394/23207.2024.21.177

[19] Shen, Y., Ab Jalil, H., Jamaluddin, R. A 10-Year Systematic Review on the Incorporation of Digital Games for Multimodal Literacy Education. WSEAS Transactions on Computer Research 2024, 12, 463-474, https://doi.org/10.37394/232018.2024.12.46

[20] Sylaiou, S., Dafiotis, P., Koukopoulos, D., Koukoulis, K., Vital, R., Antoniou, A., Fidas, Chr. From physical to virtual art exhibitions and beyond: Survey and some issues for consideration for the metaverse. Journal of Cultural Heritage 2024, 66, 86-98, https://doi.org/10.1016/j.culher.2023.11.002

[21] Vouzikas, A., Gazis, A. On the Robust Multiple Objective Control with Simultaneous Pole Placement in LMI Regions. WSEAS Transactions on Systems 2021, 20, 272-280, https://doi.org/10.37394/23202.2021.20.30

[22] Sylaiou, S., Tsifodimou, Z.-E., Evangelidis, K., Stamou, A., Tavantzis, I., Skondras, A., Stylianidis, E. Redefining Archaeological Research: Digital Tools, Challenges, and Integration in Advancing Methods. Appl. Sci. 2025, 15, 2495, https://doi.org/10.3390/app15052495

[23] Wang, X., Xiang, H., Niu, W., Mao, Z., Huang, X., Zhang, F. Oblique photogrammetry supporting procedural tree modeling in urban areas. ISPRS J. Photogramm. Remote Sens. 2023, 200, 120–137, https://doi.org/10.1016/j.isprsjprs.2023.05.008

[24] Basdekidou, V., Papapanagos, H. SEP and Blockchain Adoption in Western Balkans and EU: The Mediating Role of ESG Activities and DEI Initiatives. FinTech 2025, 4, 37, https://doi.org/10.3390/fintech4030037

[25] Wang, D., Momo Takoudjou, S., Casella, E. LeWoS: A universal leaf-wood classification method to facilitate the 3D modelling of large tropical trees using terrestrial LiDAR. Methods Ecol. Evol. 2020, 11 (3), 376–389, https://doi.org/10.1111/2041-210x.13342

[26] Xu, H., Wang, C.C., Shen, X., Zlatanova, S. 3D tree reconstruction in support of urban microclimate simulation: A comprehensive literature review. Buildings 2021, 11(9), 417, https://doi.org/10.3390/buildings11090417

[27] Leitner, D., Klepsch, S., Bodner, G., Schnepf, A. A dynamic root system growth model based on L-Systems. Plant Soil 2010, 332, 177–192, https://doi.org/10.1007/s11104-010-0284-7

[28] Qu, H., Zhu, Q., Guo, M., Lu, Z. Simulation of carbon-based model for virtual plants as complex adaptive system. Simulation Modelling Practice and Theory 2010, 18(6), 677-695, https://doi.org/10.1016/j.simpat.2010.01.004

[29] Arshad, M.A., Jubery, T., Afful, J., Jignasu, A., Balu, A., Ganapathysubramanian, B., Sarkar, S., Krishnamurthy, A Evaluating Neural Radiance Fields for 3D Plant Geometry Reconstruction in Field Conditions. Plant Phenomics 2024, 6:0235, https://doi.org/10.34133/plantphenomics.0235

[30] Hartley, Z.K.J., Stuart, L.A.G., French, A.P., Pound, M.P. PlantDreamer: Achieving Realistic 3D Plant Models with Diffusion-Guided Gaussian Splatting. arXiv 2025, 2505.15528, https://doi.org/10.48550/arXiv.2505.15528

[31] Chen, Y., Pan, Y., Li, Y., Yao, T., Mei, T. Control3D: Towards Controllable Text-to-3D Generation. arXiv 2025, 2311.05461, https://doi.org/10.48550/arXiv.2311.05461

[32] Yang, W., Feng, H., Zhang, X., Zhang, J., Doonan, J.H., Batchelor, W.D., Xiong, L., Yan, J. Crop phenomics and high-throughput phenotyping: past decades, current challenges, and future perspectives. Molecular Plant 2020, 13, 187-214, https://doi.org/10.1016/j.molp.2020.01.008

[33] Klein, J., Waller, R., Pirk, S., Pałubicki, W., Tester, M., Michels, D.L. Synthetic data at scale: a development model to efficiently leverage machine learning in agriculture. Frontiers in Plant Science 2024, 15, 1360113, https://doi.org/10.3389/fpls.2024.1360113

[34] Yang, S., Zheng, L., Yang, H., Zhang, M., Wu, T., Sun, S., Tomasetto, F., Wang, M. A synthetic datasets-based instance segmentation network for high-throughput soybean pods phenotype investigation. Expert Systems with Applications 2022, 192, 116403, https://doi.org/10.1016/j.eswa.2021.116403

[35] Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., Bengio, Y. Generative adversarial networks. Communications of the ACM 2020, 63, 139-144, https://doi.org/10.1145/3422622

[36] Ho, J., Jain, A., Abbeel, P. Denoising diffusion probabilistic models. Advances in neural information processing systems 2020, 33, 6840–6851, https://doi.org/10.48550/arXiv.2006.11239 (Accessed Date: February, 22, 2026)

[37] Heschl, A., Murillo, M., Najafian, K., Maleki, F. (2025). SynthSet: Generative Diffusion Model for Semantic Segmentation in Precision Agriculture. In: Del Bue, A., Canton, C., Pont-Tuset, J., Tommasi, T. (eds) Computer Vision – ECCV 2024 Workshops. ECCV 2024. Lecture Notes in Computer Science, vol 15625. Springer, Cham. https://doi.org/10.1007/978-3-031-91835-3_18 (Accessed Date: February, 12, 2026)

[38] Rozenberg, G., Salomaa, A. (1976). The Mathematical Theory of L Systems. In: Tou, J.T. (eds) Advances in Information Systems Science. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-8249-6_4 (Accessed Date: January, 19, 2026).

[39] Zhang, C., Zhang, C., Zhang, M. In So Kweon, Junmo Kim, Text-to-image Diffusion Models in Generative AI: A Survey. arXiv 2024, 2303.07909, https://doi.org/10.48550/arXiv.2303.07909 (Accessed Date: February, 22, 2026)

[40] Zhang, L., Rao, A., Agrawala, M. Adding Conditional Control to Text-to-Image Diffusion Models. 2023 IEEE/CVF International Conference on Computer Vision (ICCV), Paris, France, 2023, pp. 3813-3824, https://doi.org/10.1109/ICCV51070.2023.00355 (Accessed Date: January, 12, 2026)

[41] Guillard, B., Remelli, E., Yvernay, P., Fua, P. Sketch2Mesh: Reconstructing and Editing 3D Shapes from Sketches. 2021 IEEE/CVF International Conference on Computer Vision (ICCV), Montreal, QC, Canada, 2021, pp. 13003-13012, https://doi.org/10.1109/ICCV48922.2021.01278 (Accessed Date: February, 12, 2026)

[42] Ho, J., Salimans, T. Classifier-free diffusion guidance. arXiv 2022, 2207.12598, https://doi.org/10.48550/arXiv.2207.12598

[43] Saharia, C., Chan, W., Saxena, S., Li, L., Whang, J., Denton, E.L., Ghasemipour, S., Lopes, R.G., Ayan, B.K., Salimans, T., Mahdavi, S., Ho, J., Fleet, D., Norouzi, M. 2022. Photorealistic text-to-image diffusion models with deep language understanding.

arXiv 2022, 2205.11487, https://doi.org/10.48550/arXiv.2205.11487

[44] Morano, P., Tajani, F., Guarnaccia, C., Anelli, D., An Optimization Decision Support Model for Sustainable Urban Regeneration Investments. WSEAS Transactions on Environment and Development 2021, 17, 1245-1251, https://doi.org/10.37394/232015.2021.17.114

[45] Li, D., Jia, W., Guo, H., Wang, F., Ma, Y., Peng, W., Zhang, S., Use of terrestrial laser scanning to obtain the stem diameters of Larix olgensis and construct compatible taper-volume equations. Trees 2023, 37, 749-760, https://doi.org/10.1007/s00468-022-02381-2

[46] Mboma, J.G.M., Tshipata, O.T., Kambale, W.V., Salem, M., Joel, M.T., Kyamakya, K. Enhancing the Reliability of Academic Document Certification Systems with Blockchain and Large Language Models. WSEAS Transactions on Information Science and Applications 2024, 21, 419-437, https://doi.org/10.37394/23209.2024.21.39

[47] Fitriawijaya, A., Taysheng, J. Empowering Digital Twin Through BIM–Blockchain for Carbon Disclosure of Certified Green Buildings. Computer-Aided Design & Applications 2025, 22(2), 180-202, https://doi.org/10.14733/cadaps.2025.180-202

[48] Liyanaarachchi, G., Viglia, G., Kurtaliqi, F. Addressing challenges of digital transformation with modified blockchain. Technol. Forecast. Soc. Change 2024, 201, 123254, https://doi.org/10.1016/j.techfore.2024.123254

[49] Xu, J., Shan, J., Wang, G. Hierarchical modeling of street trees using mobile laser scanning. Remote Sens. 2020, 12 (14), 2321, https://doi.org/10.3390/rs12142321

[50] Davies, P.-M., Weir, P., Byrne, S., Building Educational Simulations Using KSA Open Data, WSEAS Transactions on Environment and Development 2020, 16, 802-810, https://doi.org/10.37394/232015.2020.16.83

[51] Nijhuis, S., Sun, Y., Lange, E. (Eds.). Adaptive Urban Transformation, Springer 2023, https://doi.org/10.1007/978-3-030-89828-1 (Accessed Date: February, 24, 2026)

[52] Sabba, M.-F., Lerna, M., Diaferio, M., Foti, D., Satellite Data for Structural Monitoring of Historical Building: The Temple of Minerva Medica in Rome, WSEAS Transactions on Environment and Development 2021, 17, 1284-1289, https://doi.org/10.37394/232015.2021.17.117

[53] Yfantis, V., Ntalianis, K. A Blockchain Platform For Teaching Services Among The Students. WSEAS Transactions on Advances in Engineering Education 2022, 19, 141-146, https://doi.org/10.37394/232010.2022.19.15

[54] Eze, K.G., Akujuobi, C.M., Hunter, S., Alam, S., Musa, S., Foreman, J. A Blockchain-based Security Architecture for the Internet of Things. WSEAS Transactions on Information Science and Applications 2022, 19, 12-22, https://doi.org/10.37394/23209.2022.19.2

[55] Lohmer, J., Lasch, R. Blockchain in operations management and manufacturing: Potential and barriers. Computers & Industrial Engineering 2020, 149, 106789, https://doi.org/10.1016/j.cie.2020.106789

[56] Arshad, Q.U., Khan, W.Z., Azam, F., Khan, M.K., Yu, H., Zikria, Y.B. Blockchain-based decentralized trust management in IoT: systems, requirements and challenges. Complex & Intelligent Systems 2023, 9, 6155–6176, https://doi.org/10.1007/s40747-023-01058-8

[57] Evolved software (2026). “Tree lt” free tree generator. CG journal, https://cg-journal.com/en/tree-it-basics/ and https://www.evolved-software.com/treeit/treeit (Accessed Date: February, 11, 2026).

[58] Yazdi, H., Shu, O., Ferdinand, L., A Target-driven Tree Planting and Maintenance Approach for Next Generation Urban Green Infrastructure (UGI). Journal of Digital Landscape Architecture 2023, 8, 178-185, https://doi.org/10.14627/537740019

[59] Fox, N., Lidquist, M., Berkel, V.D., Vergel, R.S., A Collaborative Augmented Reality Decision Support System for Crowdsourcing Urban Designs. Journal of Digital Landscape Architecture 2023, 8, 195-202, https://doi.org/10.14627/537740021

[60] Lin, P., Hu, G., Tse, K.T., Leung, A.K. Effects of tree geometry on the aerodynamics of sympodial trees with analysis of extreme gust wind, Agricultural and Forest Meteorology, 2025, 373, 110798, https://doi.org/10.1016/j.agrformet.2025.110798

[61] Kontsiotis, V.J., Emmanouilidou, F., Liordos, V. Economic valuation of a mesocarnivore’s impact management. Environmental Science and Pollution Research 2024, 31, 32111-32125, https://doi.org/10.1007/s11356-024-33398-4

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