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# Applied Digital Documentation with Parametric 3D Modeling and Internet of Trees Functionality for Smart Forests and Monument Landscapes

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***Author's contribution***

*The sole author designed, analyzed, interpreted and prepared the manuscript.*

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## ABSTRACT

**The Problem:** The classic traditional digital documentation (i.e. study, design, development, and maintenance of forests, parks, and monument landscapes) shows significant problems of functionality, adaptability, sustainability, velocity, and viability.

**Target & Research Objectives:** In the framework of forests, parks, and monument landscapes, the massive volumes of Big Data (greater variety, arriving in increasing volumes, and with more velocity) can be used to address documentation problems that wouldn't have been able to tackle before. Smart forest, as an Internet- enabled "product", requires Big Data because it operates in real-time and requires real-time evaluation and action. Also, the recent research and practice advances in Blockchain data structures and Distributed Ledger Technologies (DLT) support generic structures with many services (e.g. parametric functionality). Hence, a DLT smart digital documentation can address the documentation problems.

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The research objectives, for digital documentation with blockchain functionality (DLT smart documentation), are defined by grouping in user-friendly palettes generic 3D CAD modeling tools which could be parameterized (e.g. trees modeling) in order to support adaptability; and by designing a new flexible and customized GUI (Graphical User Interface).

**Methods:** The proposed methodology is based on parameterized 3D modeling of trees usually found in forests and urban parks (width and height parameters). Also, a personalized GUI operates as an interface between the end-user and the parameterized CAD (GUI palettes with many 3D modeling tools). Hence, in this paper, a parameterized 3D design is examined, analyzed, and presented in the context of digital documentation with internet of trees functionality for smart forests, urban parks, monument landscapes, and cultural heritage.

**Results:** From the research conducted the results are: (i) a personalized, innovative, and flexible graphical interface (GUI) that could be incorporated in any commercial CAD environment; (ii) many parameterized 3D design tools specialized in the development of forms, plans, and modules (e.g., parametric tree 3D models) of objects and entities found in forests, urban parks, and monument landscapes; and (iii) the introduced internet of trees operativity (software routine), ideal for smart forests, smart monument landscapes, and landscape architecture digital documentation applications with blockchain functionality.

**Application:** Possibility to support foresters, engineers, and landscape architects in development studies and documentation of peri-urban forests, recreational parks, pocket parks, monument landscapes, and cultural heritage projects. Increased integration functionality in blockchain knowledge databases.

*Keywords: Digital documentation; parametric modeling; CAD-internet of trees; CAD-blockchain integration; smart forest; smart monument landscapes.*

## 1. INTRODUCTION

Literature review and research gap analysis for research and practices in the field of Digital Documentation (Digi- doc) for forests, parks, and monument landscapes [1-5], reveals the gaps in the proposed documentation process by demonstrating significant problems of functionality, adaptability, sustainability, velocity, and viability (e.g. time delays in queries, financial costs in data capturing and storage, inability to integrate good practices and existing 3d models, application software inflexibility in dealing with research data in varied formats, high data volumes of low-density, unstructured data mining, etc.).

All Internet-enabled “smart products” like a smart forest, a smart monument landscape, etc. require Big Data because they operate in real-time and require real-time evaluation and action. Also, the recent research and practice advances in Blockchain data structures and Distributed Ledger Technologies (DLT) support generic structures with many services (e.g. parametric functionality). Hence, the need for Digi-doc solutions based on Big Data and DLT technologies is highlighted; as a DLT smart digital documentation can address the documentation gaps and problems.

### 1.1 Smart Forest and Internet of Trees

The concepts **“***Smart Forest*” (like the well-known concept “Smart Cities”) and “*Internet of Trees*” (like the new concept “Internet of Things”), used in this article, derived from IT state-of- the-art advances and define sections of a forest where topography, photogrammetry, and remote sensing is applied to collect data about environmental conditions.

One of the main objectives of Smart Forests is to detect wild-fire at their early stages [6-8]. However, the required technology for such monitoring usually demands a complex and expensive sensor and network infrastructure and requires central processing capabilities for analyzing data from several thousands of sensors [9-10].

### 1.2 Applied Digital Documentation Potential Applications

Through a series of case studies that explore a range of different applications for digital documentation, we take an experience-led look at how these datasets can enable unique types of analysis and enrich existing techniques. Monitoring and mapping change within the built and natural environment is one example, where the impact of natural erosion effects from weathering and climate change can be evaluated and used as a decision-making tool to mitigate further change [1].

With proper control, the 3D data can help quantify change over time (including volumetric calculations), visualize dimensional differences, and highlight areas of interest. This same approach can be applied to buildings to identify structural changes such as movement, surface erosion, and alterations, aiding assessments of structural stability and informing conservation strategies [1,3,5].

By adding layers of data generated by other techniques such as thermography and moisture mapping, a more sophisticated picture of how specific buildings operate can be developed, informing decision-making for future conservation and improving environmental performance. Part of this process is visualizing these datasets, and interpreting the results generated is important to both the expert and the layperson [6-8].

A key feature of digital documentation is that it offers a relatively unified platform from which to convey the information, whether it is via basic renderingof the raw data or the creation of a detailed 3D model. There are few limits to how complex the data can be. The focus should always be to convey a resultthat most accurately and coherently reflects the dataset [2-5,9].

Hence, in this paper, a parameterized 3D design is examined, analyzed, and presented in the context of digital documentation with Internet of trees functionality for smart forests, urban parks, monument landscapes, and cultural heritage.

The rest of the paper is organized as follows. In Section 2 (Methodology) the research methodology process is discussed (GUI, palettes, parametric CAD tools). In Section 3 (Results) the developed personalized GUI and the three palettes are used for a DLT smart documentation. Finally, in Section 4 (Conclusions) conducted research findings, novelties, and future further directions are presented.

## 2. METHODOLOGY

The proposed methodology is based on parameterized 3D modeling of trees usually found in forests and urban parks (width and height parameters). Also, a personalized GUI operates as an interface between the end-user and the parameterized CAD (three GUI palettes with many 3D modeling tools) [Fig. 1].

The block diagram of the research methodology process (research stages) is presented in Fig. 1.

The decision to use digital documentation should be the result of an informed look at available approaches to best recording specific objects and sites. Prior to commissioning or undertaking any system of survey work, it is vital to understandthe intended outcomes and applications of the expected results [2,10].

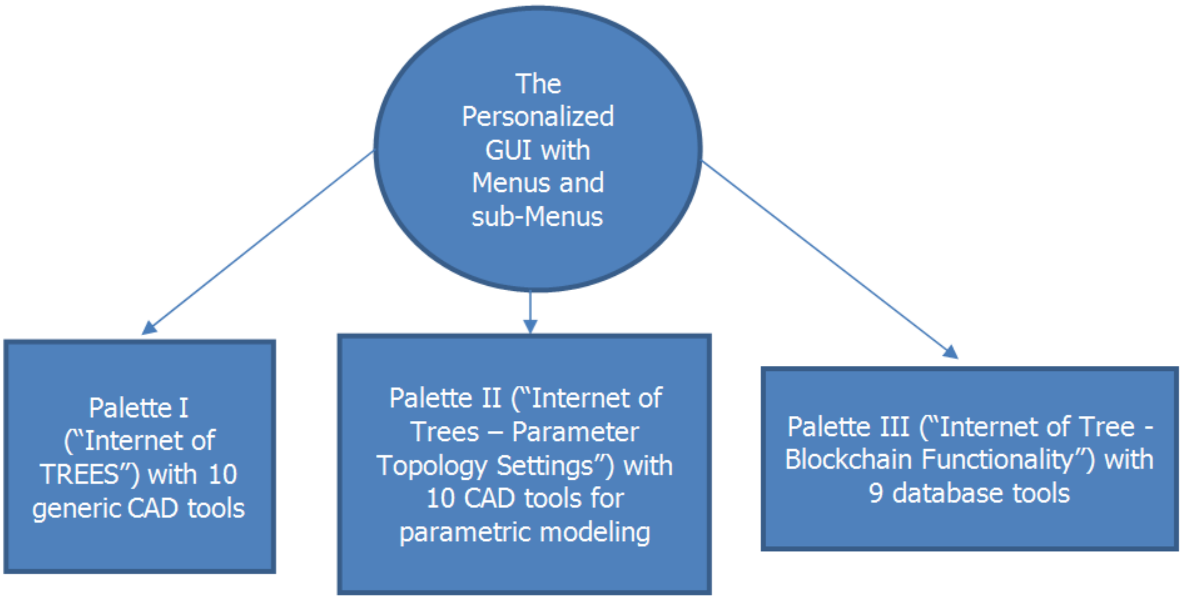


**Fig. 1. The research methodology stages**

According to *Historic Environment Scotland (Short Guide 13)*, the survey specification, fieldwork methodology and the quality of deliverables revolve around this initial assessment. To assist with this process, three (3) key conditions (Planning & Preparation, Materials & Methods, and Data Management, Analytics, and Dissemination) are presented for the consideration of those looking to utilize digital documentation as a key component or basis for their project [1].

### 2.1 The Key Conditions for Applied Digital Documentation

**Planning and Preparation**

| |
|---|
| Outline the primary objectives of the project and the specific role of digital documentation. |
| Identify the appropriate techniques for data capturing. |
| State the requirements of the project within a specification. This should describe the parameters of any survey or scheme of data capture, including resolution, tolerance (accuracy), coverage, and additional data (such photo- texturing to overlay terrestrial laser scanning). Aim to tie into existing control networks where possible. |
| Structure the data capture, processing and creation of deliverables as work packages that may be undertaken separately. |
| Address logistical aspects such as access to the site or object, handling (if appropriate) and health and safety requirements. |
| Allow for a contingency to account for uncontrollable factors that may impact the project such as inclement weather or impeded physical access. |

**Materials and Methods**

| |
|---|
| methodology meets the requirements earlier identified. This should be included in the RAMS document. |
| Clearly define the desired deliverables to be produced from the dataset, e.g. 2D CAD drawings, photo-textured 3D model. Ensure that these deliverables adhere to defined tolerances where necessary. |
| Collect relevant metadata throughout the entire data capture and processing stages. This acts as both a detailed record of the project steps and a useful tool to aid further processing and utilisation of the dataset. |

**Data Management, Analytics, and Dissemination**

| |
|---|
| Incorporate a level of quality control into all stages of data capture, processing and delivery of outputs. If a scheme of work is undertaken by a third party/external contractor (for example, a laser scanning survey), acceptance of the data should be conditional and subject to review. |
| Consider the channels and formats available for the dissemination of the data.<br>Consider Data Analytics functionality. |
| Ensure that data made are publicly available and/or released to third parties is at a minimum covered by a suitable and explicit arrangement, e.g. license agreement, statement of IPR, open access. |
| Plan to maintain and archive raw and processed datasets that may require substantial storage capacity. |

## 2.2 The Graphical User Interface (GUI)

In an applied digital documentation scheme, the graphical interface is crucial and must be interactive [2-5]. The following four images present the developed innovative interactive graphical environment (GUI) for creating and managing parameterized graphical information in a CAD environment (Figs.2-5).

Analytically, Fig. 2 presents the customized Menu Bar (1st level GUI) with Smart Forest / Smart Urban Park / Smart Pocket Park. Fig. 3 demonstrates the pull-down submenu (Smart Forest / 2nd Level GUI) with Trees / Bushes / Plants. Fig. 4a displays the pull-down submenu (Bushes / 3rd Level GUI)) with Ornamental Shrubs / Spice Bushes. Fig. 4b shows the pull-down submenu (Plants / 3rd Level GUI) with Cosmetics Seasonal Plants / Aromatics Plants. Fig. 5a indicates the pull-down submenu (Cosmetics Seasonal Plants / 4th Level GUI) with Matthiola Incana / Viola / China Aster. Fig. 5b features the pull-down submenu (Aromatics Plants / (4th Level GUI) with Thymus Vulgaris / Origanum Vulgare / Pelargonium Graveolens.

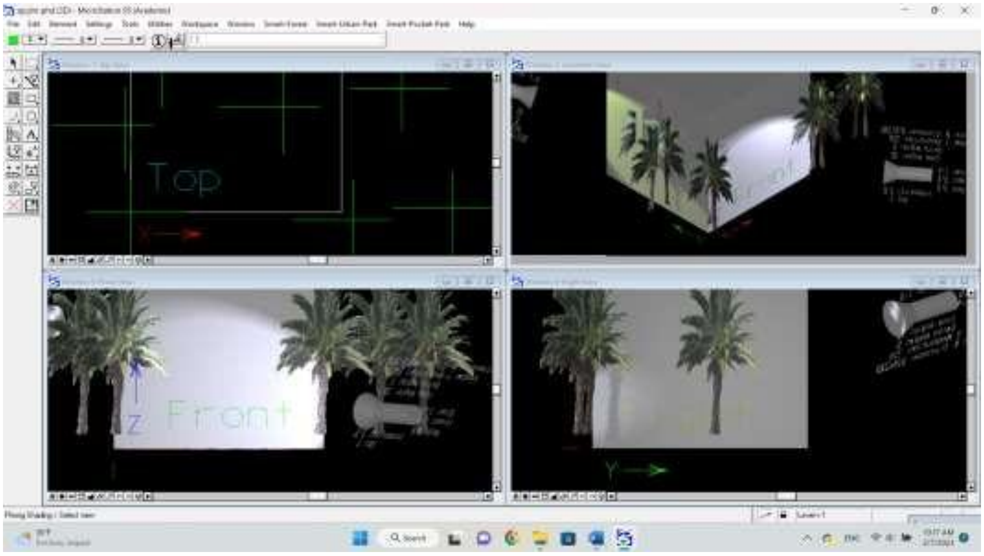

**Fig. 2. The customized menu bar: Smart forest / smart urban park / smart pocket park (1st level GUI)**

*Picture by courtesy@ D. M. Varveris (Article's author)*

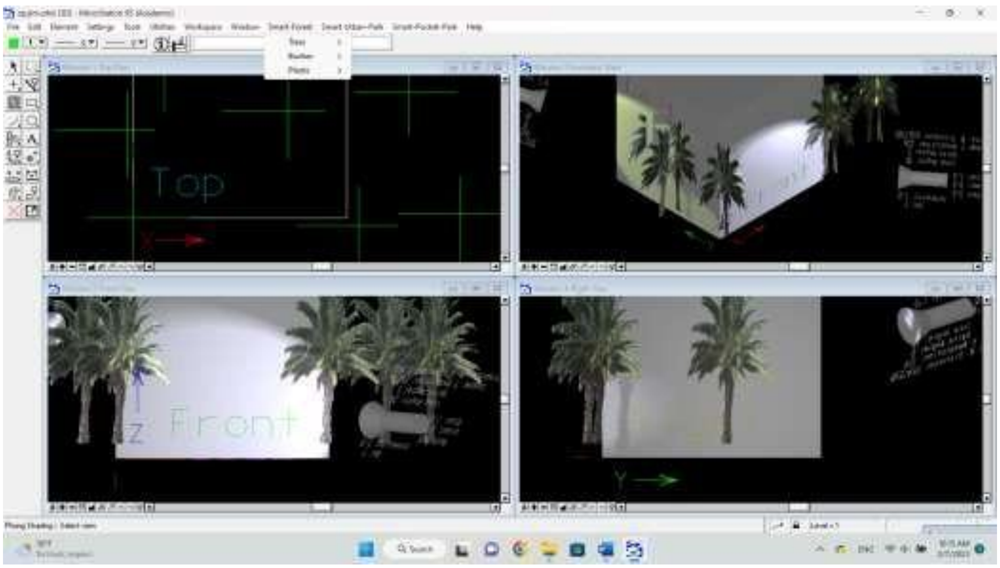

**Fig. 3. The pull-down submenu (smart forest): Trees / bushes / plants (2nd level GUI)**

*Picture by courtesy@ D. M. Varveris (Article's author)*

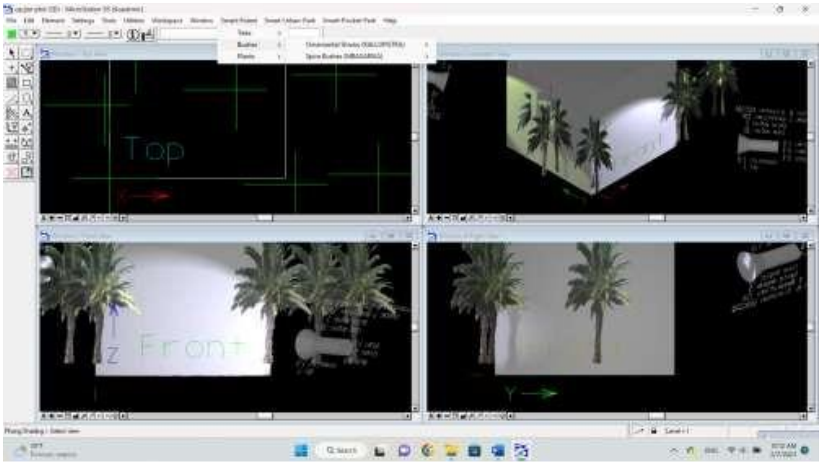

**Fig. 4a. The pull-down submenu (bushes): Ornamental shrubs / spice bushes (3rd level GUI)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

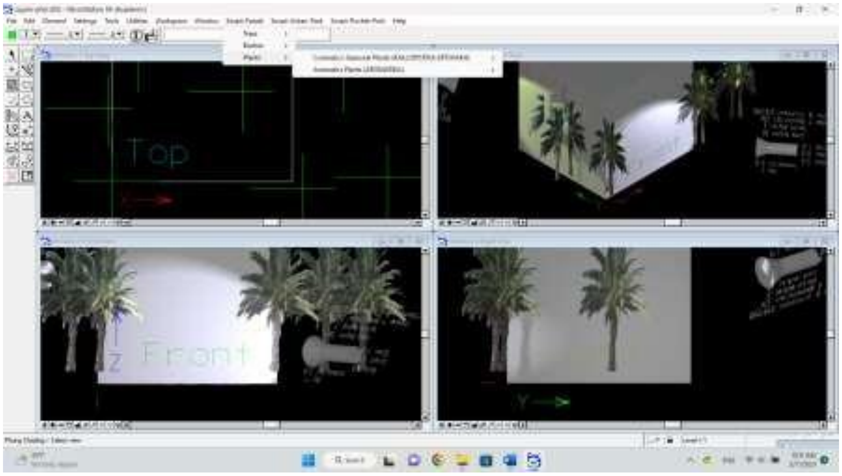

**Fig. 4b. The pull-down submenu (plants): Cosmetics seasonal plants / aromatics plants (3rd level GUI)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

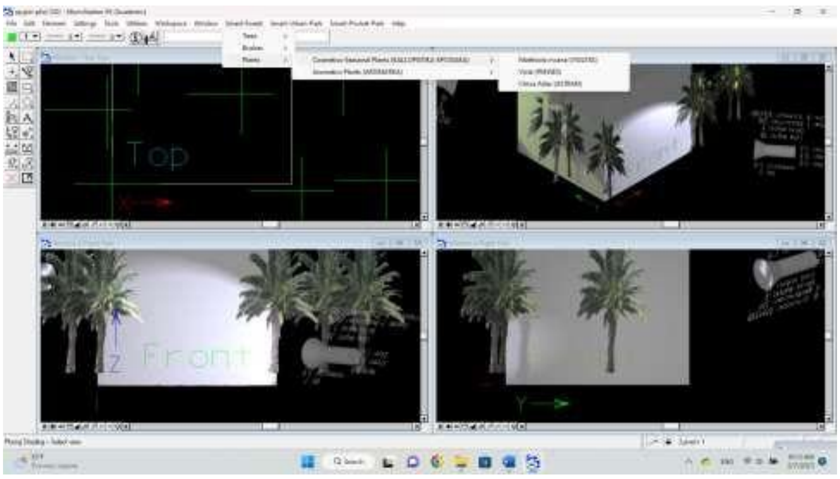

**Fig. 5a. The pull-down submenu (cosmetics seasonal plants): Matthiola Incana / Viola / China Aster (4th Level GUI)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

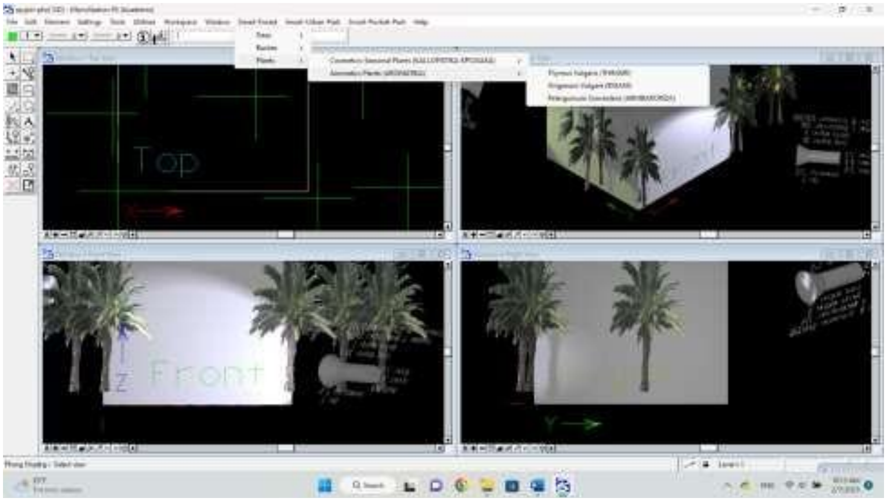

**Fig. 5b. The pull-down submenu (aromatics plants): Thymus vulgaris / origanum vulgare / pelargonium graveolens (4th level GUI)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

## 2.3 Parametric 3D Modeling

In order to develop a parametric modeling routine as a dialog function hooked in the proposed GUI, the following specifications have been defined.

**Metadata (datasets):** Three (3) datasets were used. (a) Tree species; (b) Tree dimensions; and (c) Geospatial data.

**Data sources:** For the "Tree species" metadata there are 49 tree datasets available on data.world. Open data about trees species (types) contributed by thousands of users and organizations around the world (see https://data.world/datasets/tree).

For the "Tree dimensions" metadata the tree's "width" and "height" dimensions were used as the basic parametric parameters. There are 1.097 boundaries datasets available on data.world. Open data about trees boundaries contributed by thousands of users and organizations around the world (see https://data.world/datasets/boundaries).

Finally, for the "Geospatial data" metadata there are 1.110 geospatial datasets available on data.world. Open data about trees geospatial data contributed by thousands of users and organizations around the world (see https://data.world/datasets/geospatial).

**Data types and attributes:** For the "Tree species" the data type is string-alphanumeric. For the "Tree dimensions" the data type is numeric. For the "Geospatial data" the data type is numeric.

**Source coding:** The parametric modeling routine was implemented in MDL (MicroStation Development Library). MDL code can be compiled using Microsoft Visual C++ as a native-code DLL. This both enhances programmer productivity through the use of C++ object-oriented concepts and provides better performance.

**CAD platform:** The Bentley Systems CAD platform "MicroStation V8" was used as the hosting software environment for the GUI and the parametric modeling routine.

### 2.3.1 Usability testing

Usability testing, regarding the proposed parametric modeling routine, was performed successfully by taking advances from these GUI enhancements for CAD/GIS/Visualization digital documentation applications. This is because of the cognitive relationship (a process of learning, understanding, and representing knowledge in GUI applications) between the proposed palette (tool box) and the user behavior in GUI environments. This relationship was measured successfully (usability evaluation) in a controlled MDL/C++ programming environment.

### 2.3.2 The personalized palettes (tool boxes)

According to the block diagram of the research methodology (Fig. 1), three (3) adaptive palettes (innovative tool boxes) have been developed and connected to personalized GUI's menus and sub-menus. Namely, "Internet of TREES" (Palette I) (Figs. 6-7); "Internet of Trees –

Parameter Topology Settings" (Palette II) (Fig. 8); and "Internet of Trees - Blockchain Functionality" (Palette III) (Figs. 9-10).

## 2.4 Spatial Data Acquisition and Processing

Choosing the appropriate techniques to undertake a scheme of digital documentation depends principally on the scale of the subject, the intended purpose of the dataset and the requirement for additional data (beyond spatial).

The following Table presents a categorized view of a number of 3D capture techniques regularly employed to record the natural environment for smart forest/park applied digital documentation (Table 1). Due to variation between different systems of the same type, stated accuraciesand ranges should only be treated as broadly representative [1,5].

### 2.4.1 Techniques

Data acquisition techniques (3D) has been depicted in Table 1.

### 2.4.2 On-situ field procedures

To obtain the best possible coverage of a site a range of different methodologies should be considered depending on the specification of the survey. If there are obstacles to physical access, solutions such as ropes access teams, elevated tripods, and bespoke rigs may facilitate the capture of typically hidden surfaces [1,3-6].

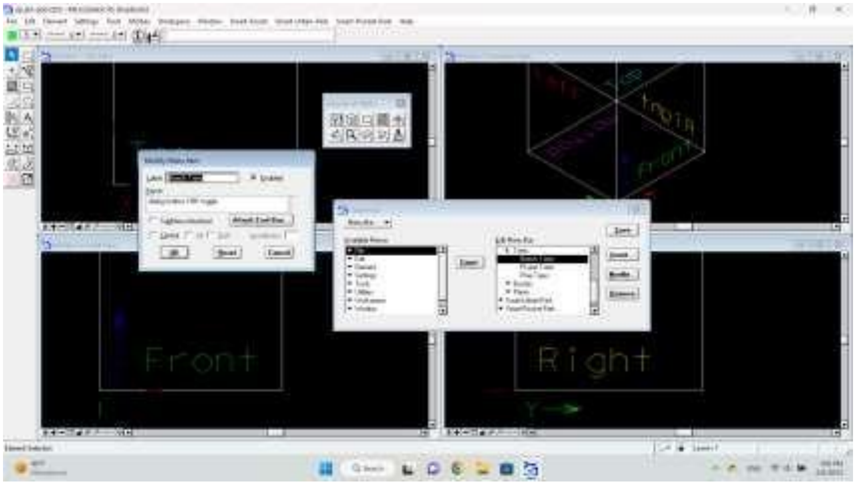


**Fig. 6. Formulating the new tool box "Internet of TREES"**
*Picture by courtesy@ D. M. Varveris (Article's author)*

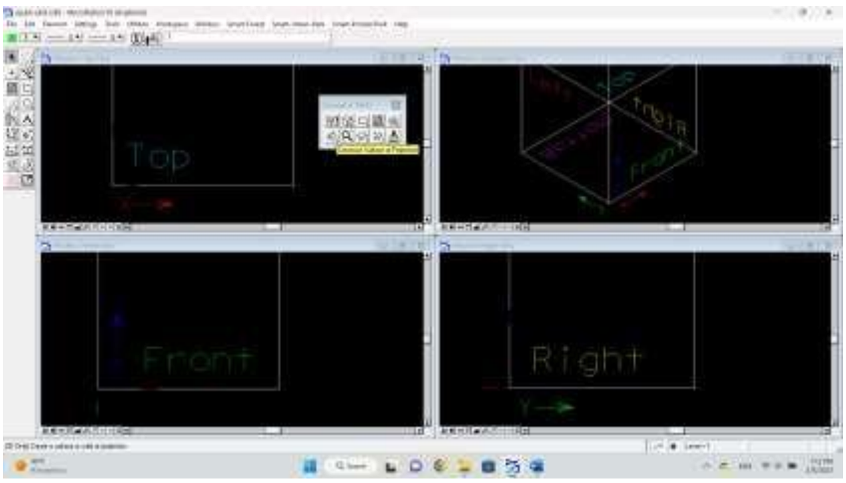


**Fig. 7. The new tool box "internet of TREES" incorporating ten (10) CAD tools**
*Picture by courtesy@ D. M. Varveris (Article's author)*

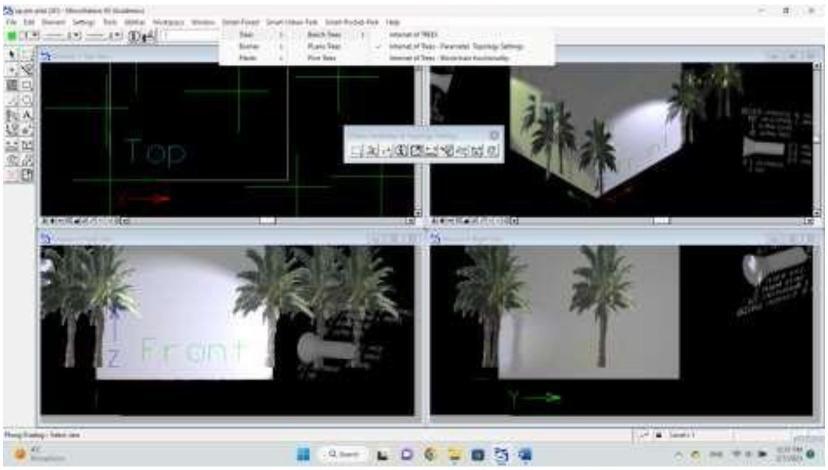


**Fig. 8. The internet of trees – parameter topology settings palette (with 10 CAD tools for parametric modeling)**

*Picture by courtesy@ D. M. Varveris (Article's author)*

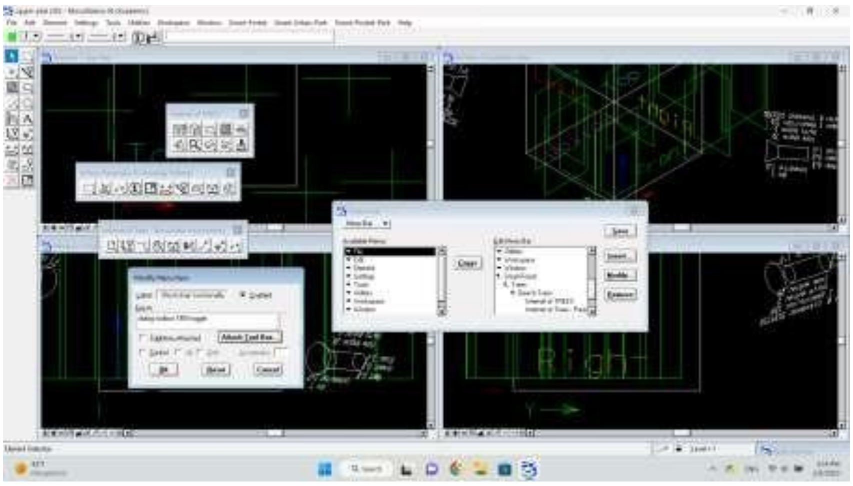


**Fig. 9. Building up the blockchain functionality tool box (a palette with 9 database tools)**

*Picture by courtesy@ D. M. Varveris (Article's author)*

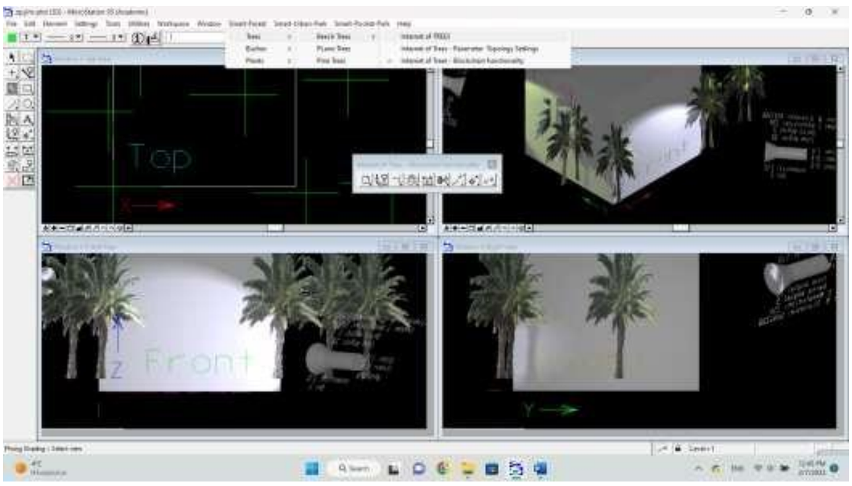


**Fig. 10. The "internet of trees - blockchain functionality" Palette (incorporating 9 database tools)**

*Picture by courtesy@ D. M. Varveris (Article's author)*

**Table 1. 3D Data acquisition techniques**

| Scale | Specific technique | Relative accuracy | Produced data type |
|---|---|---|---|
| Landscape [>km] | Interferometric Synthetic Aperture Radar(InSAR) | 300mm* | Spatial (XYZ), intensity |
| | Airborne LiDAR | 30mm | Spatial (XYZ), intensity, photo (RGB), orthophoto, classified |
| | Mobile laser scanning, e.g. boat/vehicle mounted system | 20mm | Spatial (XYZ), intensity,photo (RGB) |
| | Aerial photogrammetry, e.g. unmanned aerial system (UAS), aircraft | 30mm** | Spatial (XYZ), photo(RGB) |
| Structure [<km] | Terrestrial laser scanning (TLS) | 3mm | Spatial (XYZ), intensity,photo (RGB) |
| | Total/Multi-Station | 2mm | Spatial (XYZ), photo(RGB) |
| | Global Navigation Satellite System(GNSS) | 1-5mm | Spatial (WGS84) |
| | Simultaneous Localisation and Mapping(SLAM) | 30mm | Spatial (XYZ), intensity,photo (RGB) |
| | Structure from Motion (SfM) Photogrammetry | 3mm** | Spatial (XYZ), photo(RGB) |

** Accuracy refers to DEM derived from InSAR*
*** Results depend significantly on subject geometry, quality and quantity of input images and camera specification*

The methodology should also consider how the data will be registered together. This will necessitate either the use of targets between discrete scan positions and/or sufficient overlap of data to use 'feature' registration, wherein scans from different locations are registered together using captured data of the scanned environment. A target-based system of registration may either use traditional survey methodology, such as traverse, or re- section where scans will be undertaken at different setup locations, though not all scanning instruments have this functionality on board.

Alternatively, targets can be placed strategically between scans or even throughout the entire site.The center of the targets ('nodal point') must remain in the same position, which may mean either the targets remain static or they must be 'tilt and turn' style targets that can rotate to follow the scanner whilst preservingthe nodal point of the target.

A minimum of two common targets is required to connect scan positions; with three or more targets, one can be used to 'leap frog'to tie in subsequent scans by leaving two targets static whilst each time moving the farthest to a new position. The maximum distance between the scanner and targets depends on the system specification and resolution at which the target is captured.

Fig. 11 shows an example target arrangement to connect three (A, B, C) terrestrial laser scanning setups (ideal for smart monument landscapes surveying and recording procedures).

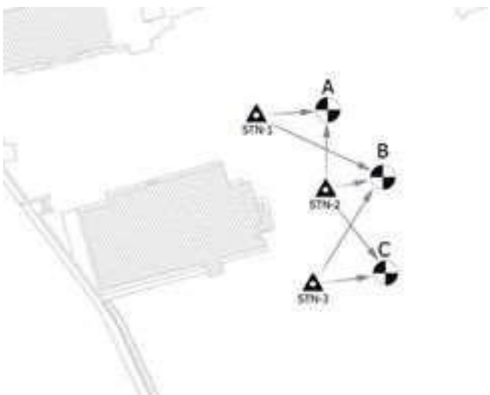


**Fig. 11. Illustrative diagram of target arrangement on site**

Positioning of scans should be designed to maximize coverage whilst achievingthe specified surface resolution. Most laser scanners will define different resolution settings. One example would be “10 mm at 10 m”, which indicates one measurement every 10 mm at a distance of 10 m in a spherical grid around the nodal point. At 50m, this equates to a point spacing every 50 mm, and 100 mm at 100 m. The higher the capture resolution, the greater the time necessary to complete the scan.

#### 2.4.3 Equipment - Terrestrial Laser Scanning (TLS)

Within the field of digitally documenting the built and natural environment, terrestrial laser scanning is one of the core techniques that enable the rapid and accurate capture of high resolution 3D data. It is increasingly central within the surveyor's toolkit, particularly for specific types of surveys where field time can be minimized and hazards associated with acquiring measured data in difficult-to-access areas can be reduced. Typically, these are tripod-mounted systems (Fig. 12) that have established workflows for data capture, integration with control networks via targets, registration software, and processing steps [1,7,10].

**Fig. 12. A tripod mounted system**
*Picture by courtesy of Historic Environment Scotland [1]*

The data produced is a collection of discrete measurements, often in the order of millions per scan, referred to as a 'point cloud'. Each individual point will have an XYZ coordinate, but potentially also Intensity (the strength of the returned laser beam) and RGB (Red Green Blue) value derived from a photograph mapped to the point cloud (Fig. 13).

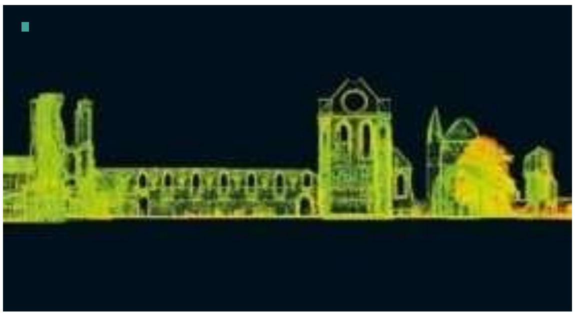

**Fig. 13. An orthographic point cloud image displayed with intensity values and silhouette shading**
*Picture by courtesy of Historic Environment Scotland [1]*

**Limitations of Terrestrial Laser Scanning:** Whilst TLS is a powerful measurement and survey tool, it should always be considered as one tool in a range of different methodologies and techniques. Some objects and environments may pose particular challenges that may better be captured with, or in tandem with, different techniques. Users should be aware of these limitations and plan a scheme of digital documentation accordingly.

#### 2.4.4 Environmental factors, cost, and calibration

TLS relies upon line of sight to the surface being recorded to successfully capture it. Planning a scheme of data capture should account for this; otherwise, coverage of the site will be poor, omitting important details such as building roof level or surfaces obscured by others. Obstacles to line of sight outside of the control of those undertaking the survey must also be accounted for, such as vehicles, foliage, temporary structures, and members of the public at sites with public access and high footfall [1,7].

Consideration should be given to undertaking the work during days when the site is closed to public access, during a different season when foliage or tree cover is less pronounced, and when weather best permits. Heavy fog will severely impede scanning and reduce the effective laser range, whilst snow cover will create extraneous data and block data capture.

There is a relatively high cost of entry for the use of TLS, with most modern commercially available scanners priced in the region of fifteen to seventy thousand pounds (prices valid at the time of publishing). New products, workflows, and the overall development of technology is reducing this, and rental of equipment should be considered where suitable.

Additional costs of software licensing, high-performance computer hardware and support should be factored in. With this in mind, the speed and productivity benefits of how surveys can be undertaken lead to significant savings in field time, including savings for physical access and health and safety (such as the erection and maintenance of scaffolding) that may otherwise incur high costs [1,6].

Scanning equipment that works within specified manufacturer's tolerances will typically require regular calibration to ensure it performs as expected. This may include returning the instrument to the manufacturer or a third party for calibration using specialist equipment or procedures, leading to downtime and incurring additional expenses. This service should be supplied with a certificate stating that the instrument meets specifications.

The same may apply to peripheral equipment such as tribraches, which are used to provide a leveling surface between the tripod and the scanner. Some equipment also enables self-calibration which can be undertaken by the user, though it should be tested and found to meet specifications before use [1,2].

## 2.5 Survey Specification

A specification is a foundation for any body of work to be undertaken,defining the key parameters and aims of the project for those involved.

**Existing specifications:** Whilst there may be advantages to developing a bespoke specification for a project that uses digital documentation, it is worth exploring existing standards that may apply. The Metric Survey Specifications for Cultural Heritage (2015) developed by Historic England (formerly English Heritage) are a detailed and thorough example, particularly for the application of terrestrial laser scanning and photogrammetry to survey within the historic environment [1,6,7].

**Purpose and brief:** Clearly state the objectives that the scheme of digital documentation will be looking to achieve and its application. One such example could includethe complete interior and exterior capture of a historic site to create a geo-referenced laser scanning dataset that incorporates existing survey control markers.

An alternative example could be the photogrammetric documentationof a collection of archaeological artifacts to create a detailed measured 3D record intended for online dissemination.

**Tolerances (accuracy and precision):** Two important concepts that require distinction in the field of spatial data capture are accuracy and precision. Accuracy refers to how close a measured value is to the true value. Precision refers to the likelihood that repeated measurements will have a similar or identical value. The specification of survey equipment should be explicit about these attributes, and some equipment willperform better than others. It is important that the tolerances of the equipmentemployed for a survey at the very least meet or eexceed the data capture requirements. These can usually be found in the manufacturer's documentation.

Accuracy may also be defined in 'relative' and 'absolute' terms. Relative accuracyrefers to the known tolerance of the specific device within stated conditions, e.g. a terrestrial laser scanner at 50m. Absolute accuracy is the value that defines how closely measurements from the dataset reflect real-world values.

**Resolution:** The resolution of a dataset will govern which features and details can be identified. It can be defined broadly by the frequency and distribution of data points across a surface. The target resolution should be determined by the desired outcomes; if a dataset should be used to produce detailed architecturalCAD drawings, a specification will look for 10 mm point-spacing (i.e. requiring a minimum of one measurement every 10 mm).

For topographic plans or a Digital Elevation Model (DEM), a resolution 250 mm may suffice. It is worth noting that whilst capture devices typically have upper resolution limits that may be limited by their design or relative accuracy, they will often allow capture at a lower resolution for flexibility. Attention should be paid to the capability and tolerancesof the capture techniques, which may be unsuitable for delivering the desired resolution. Refer to the table in section 2.1 for a quick guide to selecting the appropriate method [1,7].

**Coordinate system:** It may be a requirement of the project to situate the captured data within a specific coordinate system, such as a local site grid or the Ordnance Survey National Grid (OSNG). Spatial data defined by XYZ coordinates can be transformed to a known local coordinate system through capturing control points in common with pre-existing survey work, such as established permanentsurvey markers.

By using Global Navigation Satellite System (GNSS) or known geo-referenced points, the digital dataset can also be transformed to a varietyof other national or global coordinate systems such as the World Geodetic System 1984 (WGS84) or the Ordnance Survey National Grid (OSNG).

**Coverage:** This is the extent of how much of the site or object(s) will be captured. Coverage can be defined as the bounds or completeness of a survey, and may depend on a range of techniques and methodologies. Typically, the aim of digital documentation is to maximize data capture coverage of a site or object. In the context of a survey for example, this might be denoted by an established topographic boundary for the site, areas that are physically inaccessible, or limiting the capture to interior or exterior spaces only [1,2,3].

To maximize coverage in areas that are difficult to access, an alternate or additional approach mayneed to be considered. This may include the use of Unmanned Aerial Systems(UAS), specially designed equipment to extend or elevate capture devices or employing trained rope access teams to capture high-level detail.

**Internal and external use:** A specification should be used and referred to by project stakeholders, whether undertaking the work directly or commissioning a third party such asan external contractor. This ensures that the correct results are achieved and that the final datasets and deliverables are fit for purpose, whilst also helping to avoid problems such as a ‘scope creep’ and improve project management estimates [1,6,7].

For contracting, the same specification can be used as part of the tender process to convey the project requirements for quotations, and ensure adherence to provided standards.

## 3. RESULTS

### 3.1 Smart Forest – Monument Landscapes

Smart forests are one among many environments that are increasingly becoming technologized sites of data collection, processing, and analysis. Not just drones but also sensors, artificial intelligence, and robots are transforming forest environments in order to manage their environmental contributions through data collection and data analytics. The digital technologies that comprise these smart environments are installed on tree trunks and embedded in forest soil. They are floating airborne through forest canopies, and they are located in distant clouds and servers where data analytics unfold [6-10].

Forest technologies include unmanned aerial vehicles (UAVs), or drones, for planting trees and monitoring forest fires; sensor networks for monitoring forest processes that (in a play on the “*Internet of Things*”) have been dubbed the “*Internet of Trees*”; Light Detection and Ranging (LIDAR) scanning for assessing changes in forest structure; machine learning for automating or responding to forest events such as wild-fires; remote sensing for detecting changes in forest cover and detecting deforestation in real-time; and civic apps, platforms for monitoring forest conditions and search engines for contributing to reforestation initiatives [11-14].

The influence of emerging digital technologies on the inhabited and social spaces of forests is less well documented. At the same time, diverse types of “forests” can emerge through digital technologies, which differently sense, value, and assess forest processes and relations [7]. The promissory aspects of the “Internet of Trees” thus present as many points of consideration as the more comprehensively discussed Internet of Things. Research in this area is needed in order to further establish how these technologies both enable and constrain particular modes of governance and engagement with forests. Without this research, the development of smart environments such as smart forests runs the risk of producing social–political inequities and undemocratic governance, as has been identified with smart cities [15].

Smart cities literature has demonstrated how the digital rewiring of environments has consequences for the experience, governance, and organization of smart urban environments [16-17]. Furthermore, “smart” is a contested term, operationalized by technology companies, governments, NGOs, and community groups to advance distinct development or governance agendas [18]. The proliferation of smart technologies, infrastructures, and initiatives can shift the locus of governance from often local or urban governmental actors to more remote and global corporate actors that control technologies and networks, thereby transforming governance and participation [19-20].

While some insights from smart cities and smart infrastructure literature are transferrable to an understanding of wider smart environments, there also are numerous unstudied effects and transformations that are unique to these locations. By focusing on overlooked environments, technologies, and communities, research on smart environments such as forests can investigate what “smart” as a concept and development framework operationalizes within a wider range of locations [21] (Fig. 14).

The Blockchain functionality had been discussed in detail in [22] and it is well displayed in Fig. 14. Also in Fig. 8 the “Internet of Trees” operativity is demonstrated throw the presented innovative “Internet of Trees - Parameter Topology Settings Palette” (with 10 CAD tools for parametric modeling).

## 3.2 Internet of Trees

For the purpose of the proposed applied digital documentation “Internet of Trees” scheme, a new tool box with ten (10) interactive CAD tools has been developed (Figs. 6-7). Analytically, Fig. 6 indicates the formulating process; Fig. 7 presents the new tool box “Internet of TREES” incorporating ten (10) parametric CAD tools; and Fig. 15 displays the “Place Block” CAD tool box (Menu Bar > Smart-Forest > Trees>Beech Trees > “Internet of TREES” tool box).

The following five figures demonstrate step-by-step the developing interactive procedure for building up a smart forest with parametric trees (3D tree models) (Figs. 16-20). Analytically, Fig. 16 shows the building-up process for a smart forest: Selecting the Tree form from a graphical database (Step A’); Fig. 17 presents the building-up utility for a smart forest: Defining the parametric tree-form (Step B’); Fig. 18 indicates the building-up procedure for a smart forest: Spatial Tree-Positioning (Step C’); Figure 19 demonstrates the building-up method for a smart forest: Spot-lighting the digital smart forest (Step D’); and Fig. 20 displays the Smart Forest Visualization functionality by using the “Rotate View” CAD tool (from the “Internet of TREES” personalized Tool Box).


**Fig. 14. Internet of trees (blockchain functionality)**
*Picture by courtesy of Jennifer Gabrys [6]*

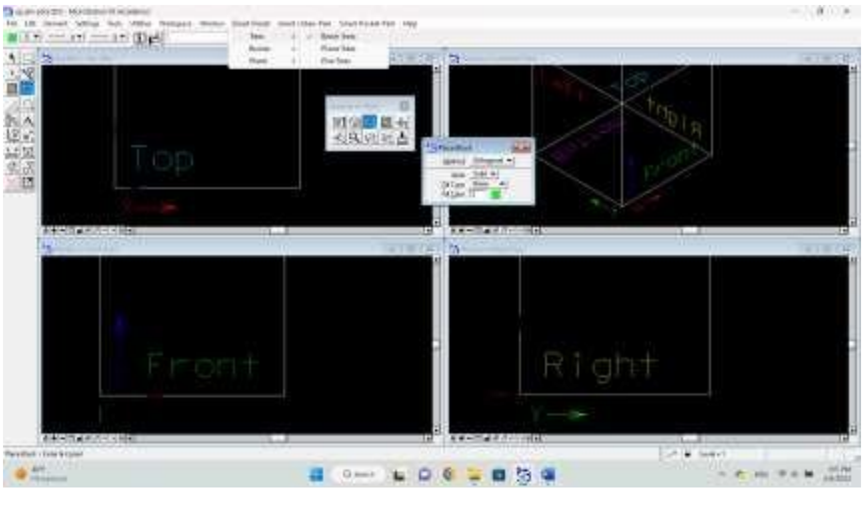


**Fig. 15. The “place block” CAD tool box (menu bar > smart-forest > trees>beech trees > “internet of TREES” tool box)**
*Picture by courtesy@ D. M. Varveris (Article’s author)*

**Fig. 16. Building up a smart forest: Selecting the tree form from a graphical database (Step A')**
*Picture by courtesy@ D. M. Varveris (Article's author)*

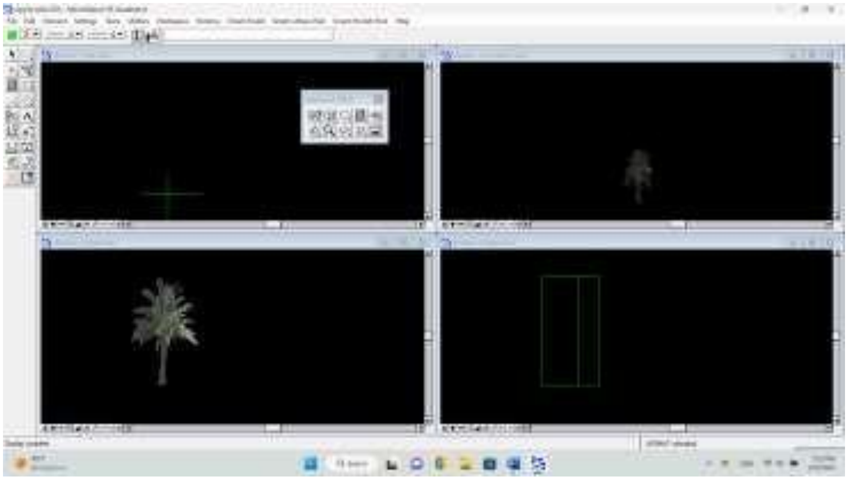

**Fig. 17. Building up a smart forest: Defining the parametric tree-form (Step B')**
*Picture by courtesy@ D. M. Varveris (Article's author)*

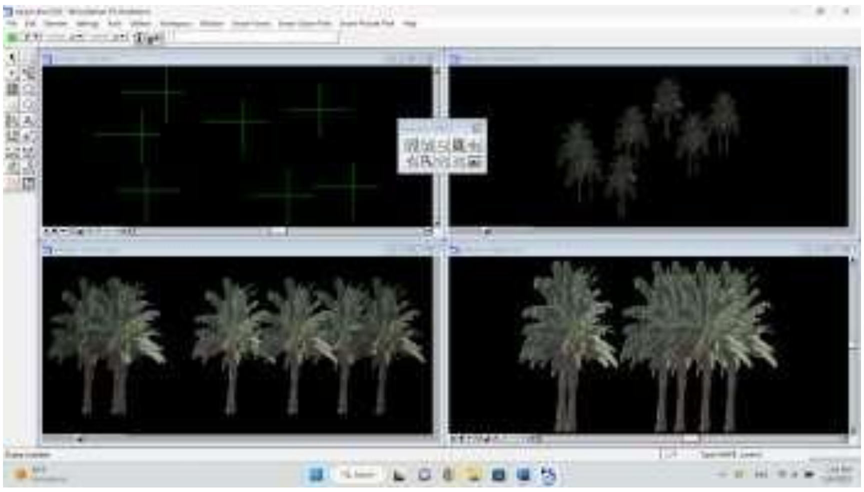

**Fig. 18. Building up a smart forest: Spatial tree-positioning (Step C')**
*Picture by courtesy@ D. M. Varveris (Article's author)*

**Fig. 19. Building up a smart forest: Spot-lighting the digital smart forest (Step D')**
*Picture by courtesy@ D. M. Varveris (Article's author)*

**Fig. 20. Smart forest visualization by using the "rotate view" CAD tool (from the "internet of TREES" personalized tool box)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

### 3.3 Blockchain Functionality

Blockchain applications have received a lot of attention in recent years. They provide enormous benefits and advantages to many different sectors. To date, there have not been any systematic studies comprehensively reviewing current blockchain-based applications in the forestry sector. This paper examines published work on blockchain-based applications in the forestry sector. A systematic review was conducted to identify, analyze, and discuss current literature on current blockchain applications deployed (and/or proposed) in the forestry sector, grouping results into three domains of forest management, traceability of forest-based products, and forest fire detection based on content analysis [22-23].

The analyses highlight reported benefits, opportunities, and challenges of blockchain applications in the forestry sector. The study results show that blockchain has great potential in sustainable forestry, minimizing illegal logging, conserving biodiversity, and many other areas in forestry. It also shows that blockchain in forestry is still immature and complex, since it requires specialists to adopt.

The current paper contributes towards filling the existing research gap through this systematic review on blockchain applications in forestry. This review offers insights into a deep understanding of blockchain applications for managers, practitioners, and consultants interested in forestry, landscape architecture, and monument landscapes (Figs. 18-20). For these purposes, a blockchain functionality tool box (actually a palette with 9 database tools) has been developed (Figs. 9-10) and presented also in Fig. 21. Finally, Fig. 22 demonstrates the connection between the “Internet of Trees - Blockchain functionality” Palette and the blockchain database throughout the internet.

#### 3.3.1 Benefits and opportunities of blockchain technology in forestry

The use of blockchain technology provides benefits and opportunities to forestry, along with multiple challenges. Minimizing illegal logging, increasing transparency, and efficient traceability are the three major benefits reported from included studies. Blockchain could help minimize or illuminate illegal logging / timber trading and brings transparency to forestry. Also, blockchain can increase traceability efficiency for tracking forest-based products.

Benefits are related to increasing forestry sustainability; minimizing illegal logging/timber trade; increasing the trust (of wood products)/trustworthiness; efficient traceability; increasing transparency; data integrity; competitive (positive); privacy; Anti-corruption; and cost reduction. In forestry, transparency means that sellers and buyers of forest-based products can rapidly access all related information (origin of wood, harvesting time, etc.) [22-23].

**Confidentiality/Privacy:** Confidentiality is one characteristic of blockchain as well. All information is anonymous because all transactions are encrypted and recorded in the blockchain [23].

**Data integrity:** Due to the characteristics of blockchain technology, data stored in the blockchain cannot be compromised [22]. The encryption and cryptography of data can reliably protect it from hacking and data breaches [23]. The transaction data in the system of smart contracts could not be changed or deleted.
And the risk of loss is minimal.

**Anti-corruption:** Data integrity and transparency are the enablers of anti-corruption. Blockchain applications can exclude corruption, embezzlement, and deception in forestry [22-23]. All parties involved in the activities of forestry can check and compare data from the database. A blockchain-based tamper-proof digital system provides social benefits such as anti-corruption from sustainable forestry.

**Eliminating illegal timber:** Blockchain technology has great potential for identifying illegal timber. Each timber is registered in the database. Blockchain technology can validate the legality of each wood/timber. The blockchain-based technical solution proposed could reject 99.17% of illegal trees in a logging area. Moreover, since timber transportation routes are planned, any deviation from the route is recorded, making illegal timber trading impossible.

A smart tree management system with drones and blockchain technology could prevent overexploitation and monitor illegal activities such as smuggling and illegal timber trading.

**Forestry sustainability:** Blockchain technology can use forest resources more rationally to increase forestry sustainability. Blockchain systems with drones can store the volume of cutdown trees to reduce deforestation, monitor the utilization of forests, and protect biodiversity draw a similar conclusion that the use of satellites and drones with blockchain technology can monitor forest resources continuously to guarantee sustainable forest management. Moreover, blockchain technology increases forest farmers’ willingness to reduce emissions (sustainability functionality).

#### 3.3.2 Challenges of blockchain technology in forestry

Although blockchain technology has great potential in forestry, there are also several challenges of blockchain implementation in the forestry sector. Blockchain technology is a new and complex technology that may not be accepted in forestry enterprises. It is difficult to apply in practice. Blockchain technology has not been well adapted in the forestry sector.

Most blockchain-based applications are developed or proposed but have not yet been widely applied in forestry. Some forest companies may not want to apply blockchain technology in their system in the forestry sector since they do not want to open their database to the public. Some forestry companies still want traditional payment and transactions in timber trading. This subsection presents and discusses the categories of challenges [22,23].

**Loss of traditional jobs:** Blockchain technology increases the risk of losing traditional and low-skilled jobs. The implementation of blockchain will eliminate many traditional jobs in accounting, credit, and international entities [22].

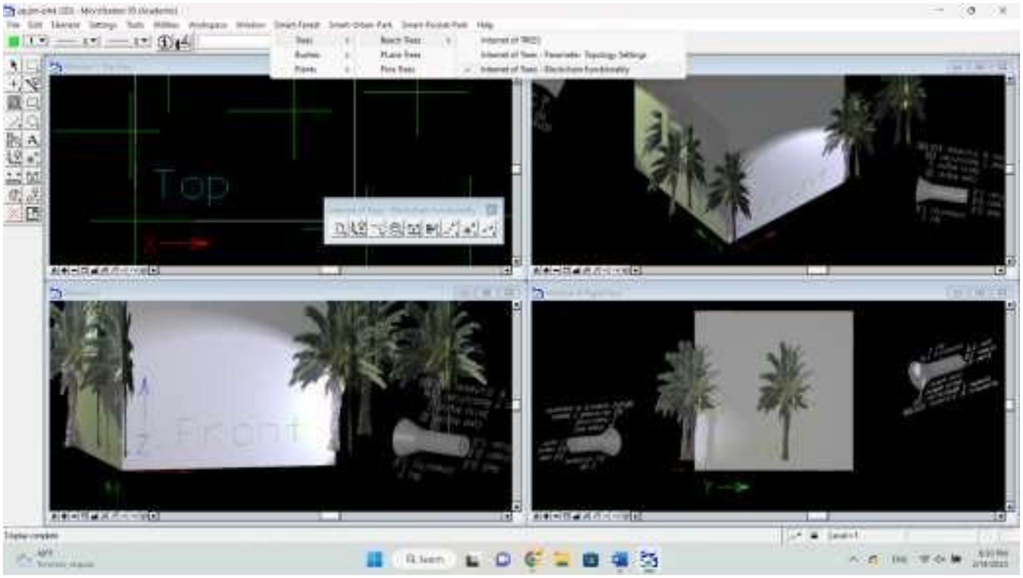


**Fig. 21. The Blockchain functionality palette (incorporating 9 database tools)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

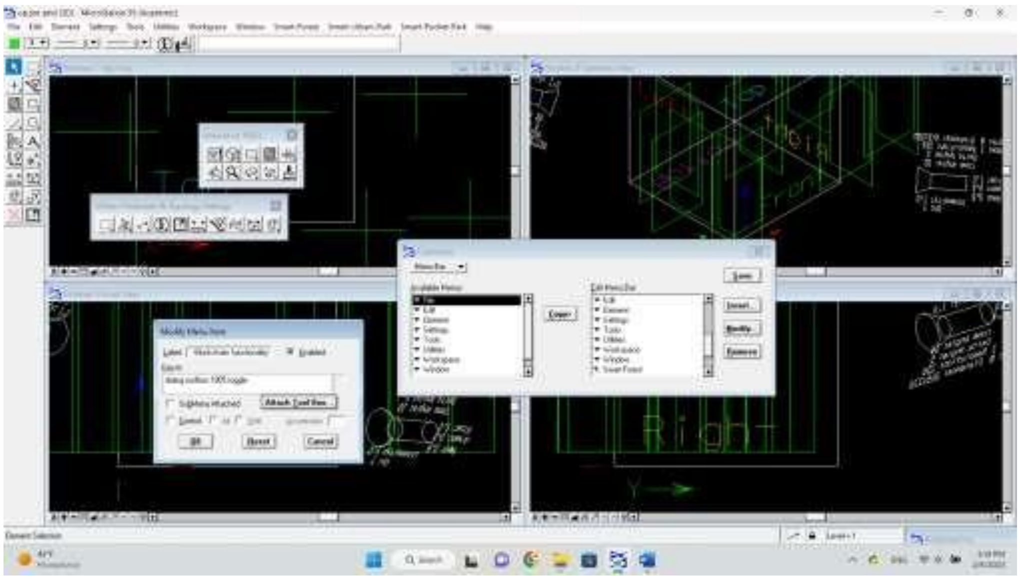

**Fig. 22. Connecting the "internet of trees - blockchain functionality" palette with the blockchain internet**
*Picture by courtesy@ D. M. Varveris (Article's author)*

**Implementation risk:** The implementation of blockchain technology could be a challenge for forestry in some countries. Cryptocurrency is illegal or not recognized in some regions and countries (such as China), therefore, using blockchain in timber trading is only theoretical and conceptual in these countries [23]. It also makes international timber trading become a challenge. If timber trading occurs in these countries, cash-out cryptocurrency will become a problem.

### 3.4 Outputs, Deliverables, and Applications

In digital documentation applications, project deliverables are decided from the outset, and typical examples include the following:

- Processed, and registered point cloud from a metric survey (e.g. terrestrial laser scanning or photogrammetric)
- Photo-textured 3D models of objects for mobile or online dissemination

- Set of Computer-Aided Design (CAD) drawings of building elevationsand plans
- Calculations of volume and area for specific features or objects
- Visualization of change over time (4D) from a programof environmental monitoring
- 3D models or content for an interactive 3D game on a computer or mobile(phone or tablet) platform, including serious games applications such as training in a virtual reality (VR) environment using VR headset technology

The capture methodology should be designed around providing the correct dataset for the creation of the principal deliverables. For example, a schemeof monitoring for a building or environment will require a measured dataset with an accurate survey control network that can be re-established periodically,perhaps including geo-referencing to the established National Grid (e.g. the Ordnance Survey National Grid-OSNG) [24-26].

Alternatively, a project looking to visualize and enable virtual access to artifacts in a museum collection, or create 3D assets for a game, may not necessitate accurate real-world scaling, but require a controlled lighting setup to obtain robust photography. It is important that any specified deliverables are completedto relevant standards, which should be defined beforehand and may vary between countries, disciplines, and intended applications.

Projects should be explicit about the number and types of deliverables and thelevel of information conveyed (e.g. 2D drawings at different scales, Building Information Models (BIM) at different levels of details, etc.). These are key factors in calculating costs and time budgets for assigned tasks, and should not exceed the initial requirements unless otherwise stated.

The strength of digital documentation is the ability to reuse datasets for a multitude of purposes, and users should balance the need to capture detailed raw data with the requirements of the deliverables. The likelihood that a higher level of detail deliverables may be required in the future should also be factored into the planning of the data capture specification.

Fig. 23 displays the three (3) tool boxes (as user-defined Palettes) developed in order to support Smart Forest applied digital documentation with parametric 3D modeling and Blockchain functionality.

(Main Menu / Smart-Forest > Trees > Beech Trees):

Internet of Trees (10 basic CAD tools);
Internet of Trees – Parameter Topology Settings (10 parametric CAD tools);
Internet of Trees – Blockchain Functionality (9 database-CAD connection tools).

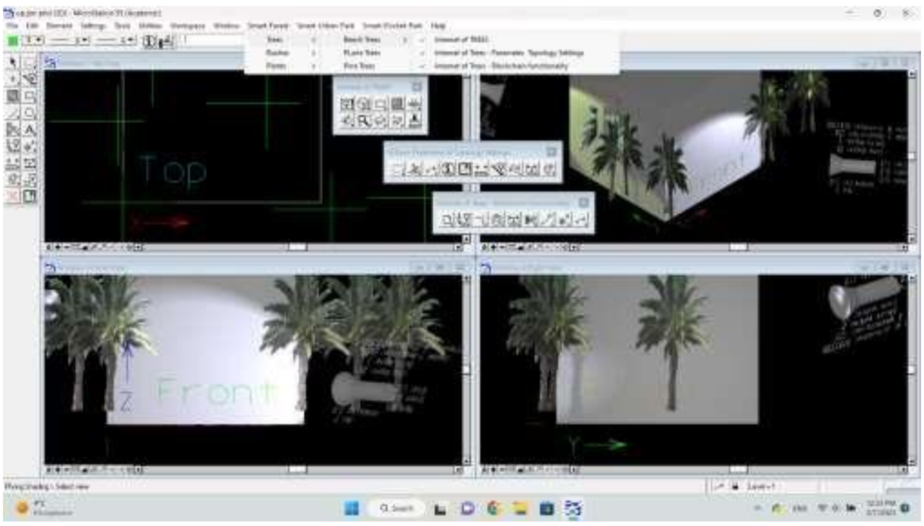


**Fig. 23. The three palettes (smart-forest > trees > beech trees): Internet of trees (10 basic CAD tools); Internet of trees – parameter topology settings (10 parametric CAD tools); Internet of trees – blockchain functionality (9 database-CAD connection tools)**
*Picture by courtesy@ D. M. Varveris (Article's author)*

A range of case studies have applied digital documentation within the cultural heritage environment for different purposes and in many countries. Key objectives, methodologies, and results will be described to introduce the projects as examples for those looking to employ digital documentation methods beyond data capture and recording [1,6,7].

#### 3.4.1 Conservation and visualization (smart forests, urban parks, landscape architecture)

The techniques and methodologies of digital documentation offer a suiteof valuable tools for the conservation of sites, monuments and artefacts. Increasing availability of non-contact and non-destructive methods to record cultural heritage has had a significant impact on conservation science, including how professionals work with material and plan conservation strategies.

As outlined by the International Council on Monuments and Sites (ICOMOS) in the charter for "*Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage*" (2003), quantitative methods should form a core part of assessment. It emphasizes approaches to 'Research and diagnosis' drawing on data to inform plans of activities for multidisciplinary teams [1].

Section 3.7 of this ICOMOS charter also notes that "*traditional*" versus "*innovative*" techniques must be "*weighed up on a case-by-case basis*", and preference should be given to the least invasive approach but also consider the associated risks and safety. It follows that digital documentation is well suited to provide a range of useful data, enabling cross-disciplinary working and offers a foundation to plan further action.

For further reading, Historic Environment Scotland makes available a series of conservation advice documents for built heritage in the form of Short Guides.These can be accessed online or in print via *www.engineshed.org*. The Institute for Historic Building Conservation (IHBC, *www.ihbc.org.uk*) and The Society for the Protection of Ancient Buildings (SPAB, *www.spab.org.uk*) also both provideconservation advice for built heritage, including professional training and CPD [1].

**Conservation monitoring:** The change observed at cultural heritage sites may be associated with challenges to the conservation of the site or its environmental context, and may reflect deterioration of its condition or developing threats that require remedial action. Digital documentation provides methodologies and tools that are suited for mapping physical change and, when integrated with other techniques available to conservation science, can build up a picture of how issues such as moistureingress of buildings or weathering and erosion are impacting the integrity of the sites.

Undertaking periodic survey and data capture can highlight the magnitudeand rate of change, helping to inform specialists and guide decisions about schemes of conservation. In order to create a record of its properties in care usingdigital documentation, Historic Environment Scotland (HES) has committed to the "Rae" project to digitally recordall of its sites, monuments and objects in collections [1].

The project also aims to facilitate a range of uses to aid in the conservation, management and promotion of the sites. The survey 3D datasets incorporate control networks, including permanent survey markers to provide a static baseline for subsequent surveys.

**Visualization:** Projects undertaken for the purpose of visualization often aim to communicateideas, designs, or conjectural scenarios in cultural heritage. The tools available to the 3D artist work well with the types of data produced by spatial and photographic capture methods, and include bespoke software suites for sculpting, modeling and animating. Moving beyond the representation of captured data may require skillsets more in common with fine art, and the use of multi-disciplinary teams has defined the capability of a number of CDDV projects.

Common outputs may include pre-rendered still images and animations, which have traditionally employed workflows that used the best tools for example to calculate lighting, develop material shaders, and render imagery. With the ongoing development of game engines, GPU hardware, and increasingly accessible Virtual Reality, there are shifting workflows thatchange productivity and artistic options for developers.

#### 3.4.2 Applications (monument landscapes, cultural heritage)

The following three examples demonstrate the 3d modeling functionality usually found in cultural heritage digital documentation projects.

Obviously, incorporating in these projects the proposed parametric modeling futures the digital documentation becomes much more flexible, adaptable, sustainable, as well as with the ability to export the parametric 3D model to a blockchain database.

**Example 1 (The Skelmorlie Aisle, Ayrshire, Scotland):** A laser scanning survey of Skelmorlie Aisle in Ayrshire was undertaken by HES as part of its “Rae” project. The site’s basement level crypt was noticed to sufferfrom moisture ingress which had led to stone degradation of the building’s masonry. A moisture analysis survey undertaken in 2013 showed the extent of the problem [1].

The dataset from the moisture survey was later projected onto the 3D dataset to better show the relationship of the moisture ingress to the structure of the tomb. The church 3D model is displayed in greyscale laser return intensity in Fig. 24.

The spatial dataset was captured using terrestrial laser scanning to record the interior and exterior of the church. The moisture survey was undertaken with a microwave moisture meter able to penetrate up to 20-30cm into the stone substrate non-destructively.

Its dataset is typically viewed in a 2D array pattern, which shows colour-graded values representing percentage moisture content. This was projected onto the 3D point cloud of the crypt in Leica Geosystem’s Cyclone (Fig. 24), with common pick-points between the moisture map and the laser scanning dataset. This process was repeated for the crypt elevations and the floor.

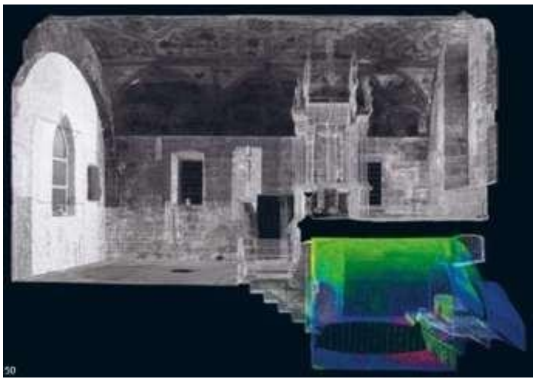

**Fig. 24. Cross-section elevation view of Skelmorlie Aisle with crypt showing mapped moisture data**

*Picture by courtesy of Historic Environment Scotland [1]*

**Example 2 (The Rosslyn Chapel, Midlothian, Scotland):** At Rosslyn chapel in Midlothian, a thermographic imaging survey was undertakento identify heat loss between the older structure and the later Victorian vestry. Fig. 25 shows the combined view of the meshed 3D terrestrial laser scan data and overlaid thermography. The colour gradient indicates temperature, with blue and cyan denoting the lower temperature areas, green the median, and yellow and red indicating areas of higher temperature. A clear ‘hot-spot’ is visible between the vestry masonry and the fabric of the original structure [1].

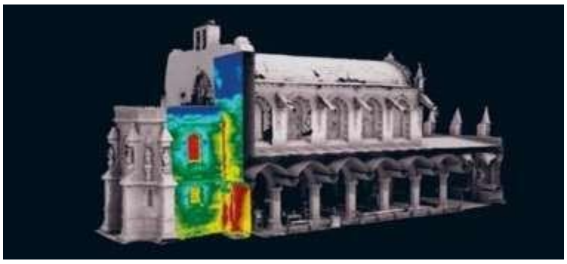

**Fig. 25. Thermography overlaid on top of the 3D mesh of Rosslyn Chapel**

*Picture by courtesy of Historic Environment Scotland [1]*

Presenting the data in a more visual way is useful for the conservation professional as it can highlight relationships between recorded values andthe structure of the site itself, helping to identify problem areas more easily.It can also be used to better communicate these issues to other audiences including non-specialists and members of the public.

The moisture survey at Skelmorlie Aisle was used to inform a plan of action to address the issues.This resulted in the installation of conservation heaters to reduce moisture penetration and further deterioration of the stone.

**Example 3 (The “Aghios Nikolaos Tranos” Church, Thessaloniki, Greece):** The Aghios Nikolaos Tranos church was destroyed in Thessaloniki’s great fire (1917). The digital 3D Model (as a part of a digital documentation project) of this demolished church was conducted using available historical photography and topological geometric constraints [27]. Fig. 24 displays four “Aghios Nikolaos Tranos” (Thessaloniki, Greece) phong-rendered views of this digital 3D model: The 3-d model with landscape (initial approach); the front view; and the right isometric view (Fig. 26).

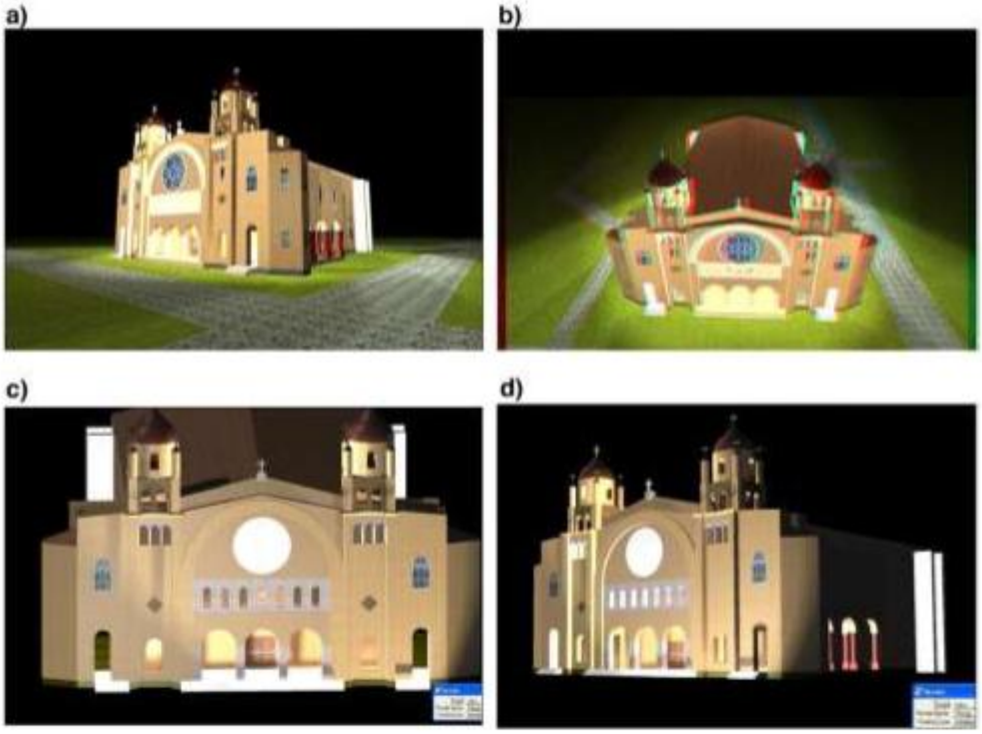


**Fig. 26. The 3D model of "Aghios Nikolaos Tranos" (Thessaloniki, Greece) phong rendered: a., b. The 3-d model with landscape (initial approach). c. The front view. d. The right isometric view**

*Picture by courtesy @ A. D. Styliadis [27]*

**Interpretation and replication via 3D printing and CNC milling:** Digital techniques allow for a wider set of resources for the interpretation in cultural heritage. They enable novel ways of presenting information to specialist and non-specialist audiences for education and offer new ways to engage the public with historic sites and collections. The following case studies identify projects that have used digital documentation techniques to enhance understanding of cultural heritage sites and objects to promote learning, community engagement, and original research. Fabrication of replicated historic objects and artifacts can provide useful tools for interpretation, enabling study and wide distribution. Techniques for replication have long existed and seen use in conservation and display, typically in the form of casting and the creation of molds, which involve contact with the surface of the object.

Digital documentation workflows enable a method for replication that is non-contact through 3D scanning, offering a more sustainable technique for reproduction and presenting an option for material that may be friable or otherwise too delicate for casting. The captured data is processed and preparedas a model that can be used for fabrication, which typically involves ensuring the model is 'watertight' by correcting non-manifold geometry (such as reversed adjacent surface normal, open edges, or overlapping polygons). This fabrication process is often referred to as 'rapid prototyping' and coversan umbrella of techniques.

Additive manufacturing is more commonly referred to as 3D printing and is the process of fabricating an object by building up layers of material intoa complete form. Materials can vary, from polymers to ceramics and metals, and the resultant prints can also be used as the base for a mold to be cast.3D printing methods calculate how the physical object will be fabricated by dividing it into discrete layers and pre-calculating the movement of either the print bed or the nozzle head/laser, depending on the technique.

There are a number of 3D printing technologies; many of these operate differently andwork to different accuracy and resolution tolerances for the printed object.These have been broadly categorized in standards documentation by ASTM International. For further reading, the

ISO/ASTM 52900:2015 standard is available online (*www.iso.org*) and in print [1]. Subtractive manufacturing, by contrast, is the fabrication of objects through the selective removal of material from a main piece of material. This is typicallythrough a process such as Computer Numerical Control (CNC) milling which operates by moving and rotating a cutting tool across multiple axes.

The materials that can be milled are only limited to those that can be worked with by tools, and typical examples include metal, wood and stone. CNC milling uses pre-calculated tool paths based on the input geometry to determine the operation of the cutting tool. The resultant object may need to be finishedor cleaned by hand to remove tool marks or smooth unwanted contours [6,7].

**Culture and environmental awareness dissemination:** The challenge of dissemination is to enable audiences and end-users to interact with and use digital documentation content, whether raw data or efficient polished 3D models. The required uses should be identified to ensure that the level of detail and information provided is not superfluous. Distribution of dataor models should always aim for efficiency such as through sub-sampling at a resolution that is appropriate. Employing techniques such as 'decimation' for 3Dmodels can retain surface details for areas of interest whilst lowering geometric detail in less significant areas (often planar topology) [27-32].

Lower-resolution files will have a knock-on impact on file size and the performance of downloadable apps and web viewers. Whilst there is ever-increasing internet bandwidth and higher speed connections, even via mobile roaming, there is still a need to present captured data in a format that is clear and well documented with metadata for the end-user [33-35]. Increasingly sophisticated methods for displaying 3D content on mobile and web-based viewers are being developed, in part due to developments in game engines and WebGL technology in tandem with GPU hardware. The repercussionsof this is the ability to disseminate and make available higher resolution 3D fileswhich would have been largely impossible a decade ago. However, content producers should account for the intended audience in terms of access and legacy hardware [27,36-37].

**Augmented reality monument landscapes and cultural heritage applications:** Augmented Reality (AR) combines 2D or 3D virtual objects and content withreal-world images to present a composite view of the two. This is typically achieved by using computer vision algorithms to track the positional information of a physical (pre-specified) target in real-time [38].

Tracking is maintained as either the device (usually a mobile device such as a phone or tablet) or the target move, enabling interactivity between the physical andvirtual objects. This technique can allow a huge range of virtual content tobe presented in an engaging and intuitive way. Fig. 27 shows an AR implementation of a 3D model viewer, displaying a real-time 3D model of the Rosslyn Chapel (created based on laser scanning and high-resolution photography) to let users explore the structure [1,39].

**Fig. 27. Augmented reality application overlaying a 3D model of Rosslyn Chapel on top of a tracked 2D target**

*Picture by courtesy of Historic Environment Scotland [1]*

As a technique that often uses real-time 3D graphics on mobile devices, AR typically requires well-optimized models, material shaders, and texture maps. The quality of tracking depends on the robustness of the tracking algorithms and the legibility of the target, which should be clear and identifiable to the device camera under well-lit conditions. If the target is unrecognizable to the device, due to poor design or other impediments (e.g. distorted, partially covered, inadequatelight) it is likely that tracking between the device and the target will be lost [38-40].

This document includes a free augmented reality app for mobile devices, allowingreaders to virtually explore 3D models of Rosslyn Chapel and the Nagasaki Giant Cantilever Crane cultural heritage sites. The 2D markers for the physical trackingof the models are included in the document appendices. The free Digital Documentation short guide companion app should be downloaded for Android and Apple iOS (search: "Digital Documentation") [1,38,40].

## 4. CONCLUSIONS

The paper answered the defined research objectives (designing a new flexible GUI; implementing new 3D CAD parameterized modeling tools; and software programming an internet of trees operativity for digital documentation with blockchain functionality) by presenting (i) a personalized, innovative, and GUI that could be incorporated in any commercial CAD environment; (ii) many parameterized 3D design tools specialized in the development of parametric 3D forms of objects usually found in forests and monument landscapes; and (iii) a software routine supporting "Internet of Trees" operativity, ideal for landscape architecture, smart forests, and smart monument landscapes digital documentation applications with blockchain functionality.

In this domain, innovative contributions include the proposed open-code routine of parametric design of 3D structural entities; and the personalized user-friendly graphical user interface hooking the innovative routine, in such a way, in order to support developing parameterized geometry and digital documentation applications tailored for smart forests, smart monument landscapes, and cultural heritage with blockchain database functionality.

The proposed GUI can be incorporated into any open-code CAD platform and should support foresters, surveyors, engineers, architects, and landscape architects in development studies and documentation projects of peri-urban forests, recreational parks, pocket parks, monument landscapes, and historical-cultural heritage sites.

Finally, future research suggestions should include the incorporation of more 3D CAD and modeling tools in the proposed palettes, new palettes design and implementation (e.g. incorporating GIS, Spatial Analysis, and Artificial Intelligence parametric tools), and a further study of the integration functionality of the proposed GUI/parametric palettes in Blockchain knowledge databases. Also, a further study of existing research gaps of Blockchain-related topics in forestry, landscape architecture, and cultural heritage, should enhance and incorporate better (i.e. with better functionality) the proposed GUI and the parametric palettes in smart forest, smart monument landscapes, and Internet of Trees DLT digital documentation environments.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the author, without undue reservation, to any qualified researcher.

## ACKNOWLEDGEMENTS

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## COMPETING INTERESTS

Author has declared that no competing interests exist.

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## GLOSSARY

**Accuracy** – How closely a measured value reflects the true value.
**Albedo** – The amount of light reflected vs. absorbed by a surface, often expressed as a percentage.
**Azimuth** – Angles measured clockwise from a reference meridian.
**Cartesian** (i.e. coordinate system) – A coordinate system that assigns two (for 2D space) or three (for 3D space) numerical coordinates for a point.
**Checksum** – An algorithm designed to create a unique code or string based on input data to detect difference between two datasets. Examples include Cyclic Redundancy Check (CRC), SHA or MD5.
**CNC** – Computer Numerical Controlled milling is a subtractive manufacturing process using a multi-axis tool following pre-calculated paths to create a physical representation of a 3D model with a high degree of accuracy.
**Control** – A stable frame of reference used to provide a baseline for measurements.
**GSD** (Ground Sample Distance) – The known real-world scale of an image pixel.
**IMU** (Inertial Measurement Unit) – A device used to measure forces and angular rate using a range of sensors such as accelerometers, gyroscopes and magnetometers.
**LiDAR** (Light Detection and Ranging) – The use of laser light to determine distance to an object or surface.
**Manifold geometry** – 3D model or mesh geometry that can be unfolded into a continuous flat piece. Non-manifold geometry includes topology with two or more faces that share a vertex but no edge, adjacent faces with no normals and three or more faces that share a single edge.
**Mesh** – In the context of 3D data, a mesh refers to polygonal geometry generated directly from point cloud data.
**Nadir** – Lowest point / direction directly below a position. Opposite of zenith.
**Noise** – Typically taken to either refer to either, (a) any extraneous data accidentally collected or generated during data capture, or (b) uncertainty component of a laser return signal, usually specified by manufacturers.
**Orthoimage** – Image geometrically corrected (“orthorectified”) such that the scale is uniform.
**Point cloud** – Group of discrete 3D data points, typically generated through spatial data capture.
**Precision** – How closely repeat measurements agree. Arithmetic precision refers to the total number of digits used to represent a Fig, e.g. number of decimal places.
**Projection** – In the context of mapping, the transformation of 3D coordinates onto a 2D plane.
**RADAR** (Radio Detection and Ranging) – The use of radio waves to detect objects or surfaces and determine their range or velocity.
**Shader** – An algorithmic instruction that governs the representation of a surface or 3D object and its response to lighting. May have adjustable parameters that depend on the type of shader.
**Structure from Motion** (SfM) – A photogrammetric technique that uses bundle adjustment algorithms to simultaneously calculate subject topology and camera position and orientation.
**Topology** – In the context of 3D models and meshes used to refer to the qualities of the surface geometry. ‘Retopologising’ refers to the creation of different geometric representation of a surface or object,
often used in the context of cleaning or reducing polygonal/triangle count in 3D models.
**Transformation** – A mathematical operation to convert a dataset between coordinate systems.
**Zenith** – Highest point / direction above a position. Opposite of nadir.



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