Comparative Navigation System for Collaborative Project

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ABSTRACT

We investigated the concepts, strategies, and functions of a 3D virtual design environment for collaborative, real-time architectural design using our 3D comparative navigation system and virtual reality technology. The development of the 'comparison' concept has enabled interactive design in real time in a 3D computer environment. Since participants must be able to easily understand the proposed design systems that help them gain this understanding are required. While comparison is an effective way to gain such an understanding, comparing one proposed design to another using existing systems is difficult because the user must operate their viewpoints separately. We therefore created a prototype system that displays different contents simultaneously while controlling the viewpoints automatically to facilitate content comparison. This comparative navigation system facilitates comparison of proposed designs by displaying related parts of the designs automatically. In this paper, we describe the concepts, strategies, and functions of a 3D virtual design environment for collaborative, real-time architectural design that is based on our 3D comparative navigation system and real-time simulation technology. We also evaluate the advantages and disadvantages of using this design environment for collaborative architectural design.

Keywords
Collaborative design, Experience, Comparison, 3D Digital archive, Interactive, Real-time simulation.

1. INTRODUCTION
The use of 3-dimensional computer graphic (3DCG) models as an architectural design tool has have been increasing in recent years. Awareness of design has been increasing, and awareness is essential for efficient architectural rendering and agreement between participants. Both specialists and non-specialists can more effectively understand a design by using 3DCG.

The inspection of designs by participants and the demand for presentations are high. Various viewpoints need to be considered in collaborative design, not only the viewpoints of the enterprise body or designer. There is also an increasing demand for designers to be able to respond immediately to demands in presentations.

Collaboration up till now has involved the creation of still pictures or animations from a viewpoint assumed in advance. But it is difficult to guess all the assumptions for all the needs that the participants. Moreover, during collaboration responses cannot be immediately made to spontaneous needs.

Here we focus on a 3D real-time simulation engine as a design tool that solves these problems immediately. It would provide an effective, interactive, and rapid design platform. It could be applied to all stages of the design process and be used to check the designs at any time, anywhere, and at any stage. Its support of visualization and interactivity would enable good communication between the client and designer, thereby reducing misunderstandings. The real-time interactive previews it would enable should become a major part of the design process.

The rapid increase in the power of personal computers along with the drop in their prices has led to the migration of visual simulation and computer animation applications from expensive workstations to inexpensive PCs. We can now obtain faster rendering and higher quality results from PCs. The development of 3D real-time visual simulation has enabled the rendering of high-quality images at high speed.

Architectural design involves two major components, i.e., photorealistic and scenario scripting, which

enable participants to feel a greater sense of realism. In the field of entertainment, movie makers and video-game programmers are investing a great deal of economic and human resources in developing a good interactive interface, e.g., a 3D real-time simulation engine. The entertainment field is expanding very quickly. This field has grown considerably over the past few years, and hardware and software are approaching perfection.

The aim of our research was to develop a good, interactive 3D development platform. It arose from an urgent need for 3D real-time simulation techniques that could be used to produce better architectural designs. We therefore focused on applying a real-time simulation engine to architectural design.

Comparison for Collaborative Project

The participants in a design project must understand the proposal on which they are working. Systems that help them gain this understanding are therefore required. Comparison is as an effective method for assisting understanding. For example, the representation of a person can be compared with that of an object to help the user better understand a certain object. By considering the differences, the user can recognize and understand an object. That is, the user compares and contrasts to clarify the areas with similarities and differences, enabling the user to recognize each similarity and difference. Therefore, we put considerable emphasis on comparison. A person can clarify the correlation, the effect, and the causal relation of objects by multilaterally comparing the objects. In addition, a person can deepen his or her understanding of each feature of the contents being compared, resulting in a better overall understanding of the whole.

Comparing one type of content to another using existing systems is difficult because users have to locate contents and observe them from separate viewpoints. With this in mind, we developed a prototype system that simultaneously displays various types of content while automatically controlling the viewpoints, enabling the user to easily compare them. Such a comparative navigation system facilitates comparison of design proposals by displaying their related parts automatically. Our 3D comparative navigation system is semantically a 3D extension of such a system. In the real world, people can walk through only one space, while in virtual space, a user can walk through many spaces at the same time. This is a key concept of our system, and it is intuitive and effective.

Digital Archive for Comparison

Digital archives initially included only text and photographs, while they now include photographs, videos with text explanations, and 3-dimentional computer graphic (3D CG) models. In the architectural field, for example, the use of 3D digital models for computer-aided design/computer-aided manufacturing (CAD/CAM) has improved the efficiency of design, construction, and management. The 3D model can be of huge objects that one can walk around, such as places with historical architecture or archaeological sites. The digital archives described in this paper assume a 3D model, hence the term '3D digital archives.'

Many case studies reflecting the expansion of 3D digital archives have been presented at international conferences [1–4]. The main focus of these studies has been the construction of the archives. There have been few reports of research into how such archives can be used or how they can be experienced.

The main feature of 3D digital archives is that users do not simply see a flat 2D image of the contents out of context—they can see the contents from all angles in a natural setting. In addition, users can experience the contents as if they were in the real world. Moreover, they can run simulations and scientific investigations that would not be possible in the real world.

2. NAVIGATION FUNCTION FOR COMPARISON

To gain an understanding by comparison, we need to consider the original purpose and objective first. The content to be used changes on the basis of the comparative purpose and comparative object.

We have been examining various types of comparisons used in design projects over many years. The comparisons were made using various media, such as real-time simulation, animation, and still pictures. The functions required for comparison navigation were extracted by examining the comparison techniques used in the design projects. To generalize the comparison techniques and make them suitable for sharing, we arranged the main contents used for the comparisons on the basis of two viewpoints.

- Comparison of the differences in existence, form, and size to reveal the identity, similarities, heterogeneity, and features of 3D structures.
- Comparison of the changes in an object over time to reveal the similarities and differences at each stage, thus giving a picture of the change process.

The functions of comparison navigation were considered based on these two viewpoints. Users can

compare different contents to help them understand particular content. By considering the differences, users can recognize and understand the content. They can also clarify the relationships, effects, and causal relations between different contents by comparing the contents multilaterally. In addition, the process of comparison makes it easier to identify different features of the content, encouraging greater understanding. The functions were arranged in accordance with the comparison purpose, the target content, the viewpoint setup, the viewpoint movement, the screen separation, and the content expression. Consequently, ten functions were identified for general comparison navigation; screen division comparison, photograph/model comparison, transparency change comparison, superposition comparison, model change comparison, camera viewing angle change, shadow display, comparison object insertion, measurement, and guide map display.

We developed a comparative navigation system that uses these functions and real-time simulation to facilitate interactive comparative studies of 3D architectural designs.

3. COMPARATIVE NAVIGATION SYSTEM

In this section, we describe the development of our comparative navigation system for a 3D architectural design and our prototype system.

Development

We used various tools, including an authoring tool, a modeling tool, and an image-editing tool, to develop this system. The main technology used was real-time simulation technology based on virtual reality.

We used the Microsoft® DirectX Graphics-Application Programming Interface (API) based Virtools®, an authoring tool commonly used to develop computer games, to develop the internal scripts (Figure 1) comprising the real-time simulation graphical user interface (GUI). Producing architectural simulation is an impossible task for non-professional programmers, and architectural designers basically have no idea of how to produce a 3D scene. Virtools' building block system was specifically designed to meet the needs of cutting-edge interactive 3D development and is the only interactive 3D authoring tool accessible to non-programmers. Building Block is a subprogram packaged in a dynamic link library.

We assign building blocks in the scene as object behaviors through the visual authoring interface. We can then modify the scene by linking building blocks (using another subprogram). Specifically designed to meet the production needs of cutting-edge

architectural simulation, the building block system provides the groundwork and tools users need to unleash their creativity and harness the full potential of the 3D real-time simulation engine. Users can import industry-standard media files to the building block system as 3D models, textures, characters, sets, and sounds. They can attach behaviors to these entities to create interactions. They can control and tweak the behaviors to form a higher-level element that forms the foundation for interactivity or simulation. The building block system's intuitive GUI enables real-time 3D environments to be designed and instantly experienced in an interactive sophisticated manner. Behaviors can be collected from a multitude of sources (libraries, other projects, etc.) and be exchanged over the Web. This system's open architecture makes all the behaviors compatible, so they can be recombined with existing modules. The interface is constructed using Virtools® scripts, as shown in Figure 1.

Specifically, we used a note PC with a 4.3-GHz CPU, an ATI Radeon® 9800 GPU, and 2-GB RAM. To enable us to perform the rendering in real time with smooth movement, the rendering had to be done at no less than ten frames per second (FPS). This system was designed for comparative navigation in collaborative architectural design. The system had to meet three conditions in particular for it to support real-time simulation.

1. *High-speed rendering*: There is a trade-off between a high sense of reality and high-speed rendering as the system may not have sufficient performance for both. Priority was thus given to rendering at high speed to archive real-time simulation. The system also had to ensure the highest sense of reality.
2. *Lightweight 3D data*: One way to increase the rendering speed is by reducing the weight of the data. A balance needs to be found between sufficient data speed and a sense of reality. Moreover, the user should not feel impatient while using the system through the Internet. That is, the system should be able to read the 3D data in less than 90 seconds. This can be achieved by selecting suitable hardware and software.
3. *Easy operation interface*: The interface should be easy to operate. In situations where operation does not keep up with the rendering, the rendering speed should be reduced. Moreover, the interface should be immediately usable, even by a first-time user.
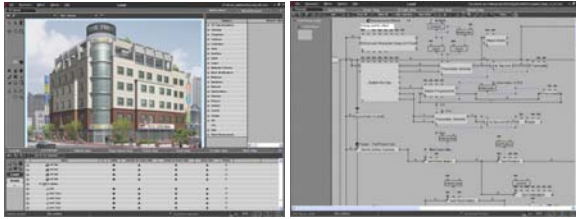
Figure 1. Scripts of real-time simulation interface developed using Virtools®.

System Outline

This system enables a general user to construct a building in virtual space. The internal and external design models for the building are first recorded on the modeling server. If the name of the building that the user wants to access and use for the server for network distribution is already defined, interior and exterior space models suitable for it are retrieved from the modeling server. Moreover, if a design proposal to use it is already defined, the model is loaded from the modeling server and sent to the user. The user can design the proposal while manipulating the model in virtual space. The user can also record the data on the server using his or her ID. The system concept is illustrated in Figure 2.

1. The user accesses the web and selects a model from a menu.
2. The web server sends a request to the database management system (DBMS) for information about the requested model.
3. The DBMS sends the uniform resource locator (URL) of the file server containing the requested information.
4. The web server sends a request to the file server for the target file.
5. The file server sends the requested file.
The web server displays the file contents to the user.
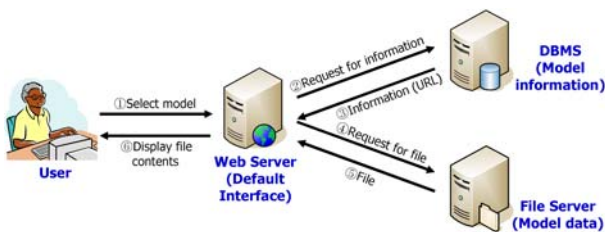
Figure 2. System concept

Prototype

The prototype system supports a traditional walk-through simulation and is especially aimed at enabling users to experience the archive information through browsing in the following ways.

- As the user freely walks through the archives, the system provides on-demand comparative views of related content.

- If the user 'collides' with a model wall, a collision detection function generates a rebounding effect, similar to the impression received when colliding with a wall in an actual building.
- The user's view is fixed at eye level by a 'gravity' function. The user does not 'sink' into the floor or 'float' above it but rather walks around as in the real world.
- The user can compare the various types of archive contents interactively. As soon as the user selects contents to be compared, the system displays them.
- The user can select from several interfaces—a mouse, a keyboard, a game controller, and a space/mouse traveler.

The process of making a comparative navigation system for a 3D architectural structure experience can be divided into five steps (Figure 3).

Step1: Gather all data created by the modeling work; 3D models, GIS models, photos, etc.
Step2: Convert the data into models using modeling tool. Then group the models together to form scenes within a circumference setting, a material setting, and alterable models.
Step3: Assign attributes and behaviors to the objects and scenes in the setting, including the camera settings, light settings, collision detection settings, level of detail (LOD) settings, and gravity settings. Also create the GUI and system functions.
Step4: Export the comparative navigation system for the 3D digital archive experience for testing and debugging.
Step5: Save behavior blocks, scenes, etc. constructed during testing in the database.

The GUI operates as shown in Figure 4. The user can compare various types of 3D digital archive by switching between one-screen comparison, two-screen comparison, and four-screen comparison.
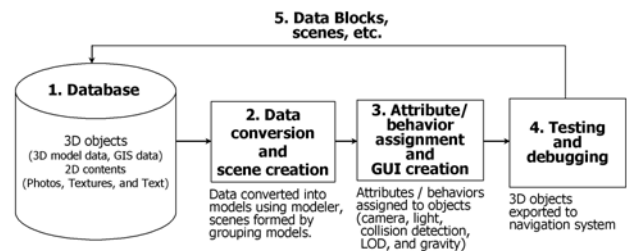
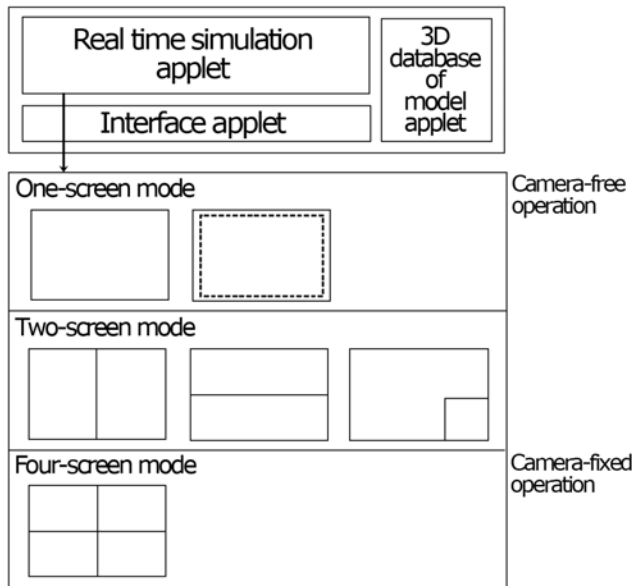**Figure 3. Steps in creating comparative navigation system**

Figure 4. Operation of GUI

Functions

This chapter will show the functions of the system . It will then present a method of improving a scene in a real project. In practice, we constructed a prototype system using the 3D digital archives of the historical architecture of a church on Gemiler Island in the Turkish Republic. This will be used to explain the functions of the system. The main functions of the system are 3D space move, plug-in, concurrent comparison navigation, and cross-section viewing function.

3.1.1 3D space move function

The basic functions for moving in 3D space are 'free walk' and 'free flight.' They enable a user to examine a proposed design in 3D space. The user can freely start at any point and move freely in 3D space.

Figure 5. 3D space move function

3.1.2 Plug-in function

Using a system like that illustrated in Figure 2, a user can choose the data insertion function from a menu on the screen. The system then loads a 3D model who the user chose from the data base for the design. The 3D model can be arranged freely. Moreover, the rearrangement is also possible after arrangement, rotation, and scale change.

Figure 6. Plug-in function

3.1.3 Concurrent comparison navigation function

Concurrent comparison navigation enables the user to comparatively examine a design proposal on one, two, or four screens by using easy key operations. In one-screen mode, the user can compare two proposed plans on the same screen. In two-screen mode, the user can compare two or more proposed designs by dividing the screen, as shown in Figure 4. In four-screen mode, the user can compare a proposed design with a photograph, etc.

3.1.3.1 One-screen mode

● *Superposition comparison*: Position and size can be compared by layering two types of content and adjusting the transparency of one of the other, as shown in Figure 7.
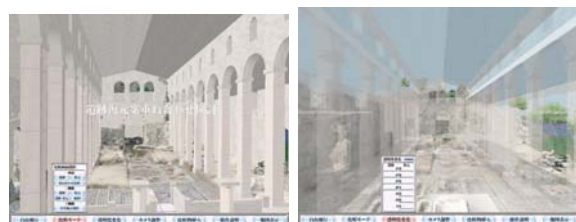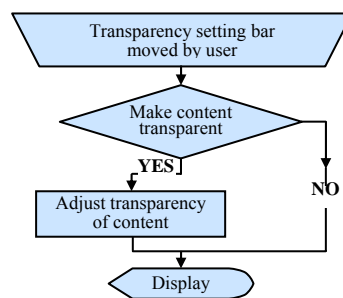

Figure 7. Superposition comparison

● *Object insertion comparison*: Size and scale can easily be grasped by inserting and displaying a 3D model of an object with a known size and scale, as shown in Figure 8.
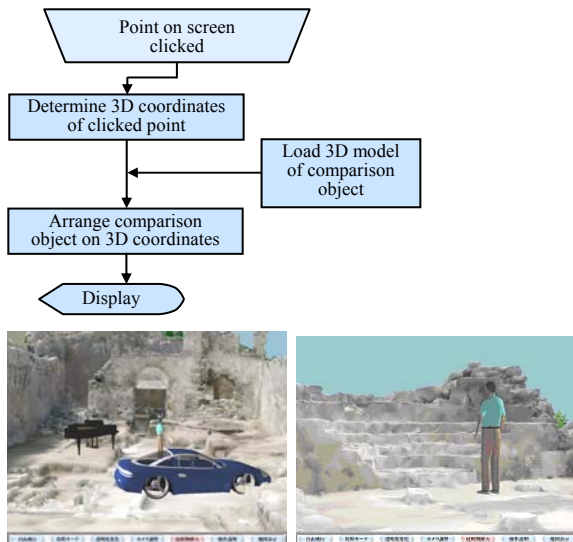
Figure 8. Object insertion comparison

3.1.3.2 Two-screen mode

● *Two-screen comparison by vertical/horizontal screen division*: A user can compare contents while walking in a virtual space by displaying two types of content in two spaces on the same screen simultaneously, as shown in Figure 9. A camera and an aspect are defined for each space, enabling the user to better understand the space composition. A camera controller is displayed in each space, and the user operates it to adjust the view. A controller can also be displayed at the center of the screen for operating the two cameras simultaneously, enabling the user to traverse the same route in both spaces.
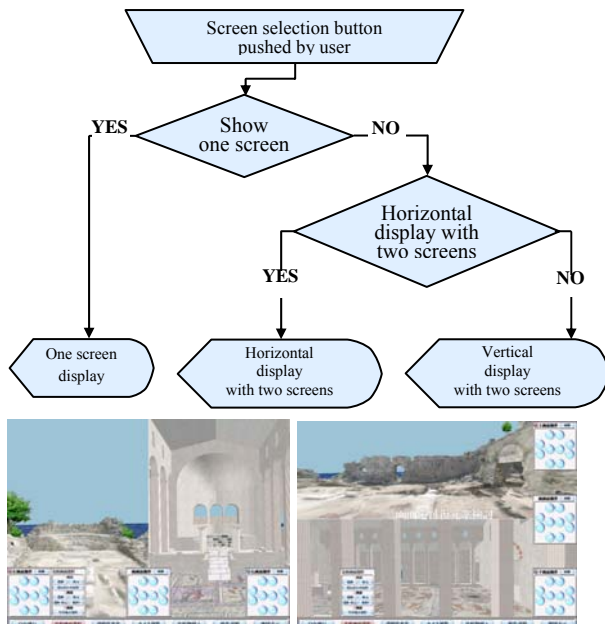

Figure 9. Two-screen comparison

● *Two-screen comparison with guide screen*: A third, smaller space can be added to show in more detail one of the two contents being displayed, as shown Figure 10. Using this 'guide screen' enables the user to focus on one of the contents and look at it in depth. The contents displayed in the corresponding main space can be changed to match those of the guide screen.
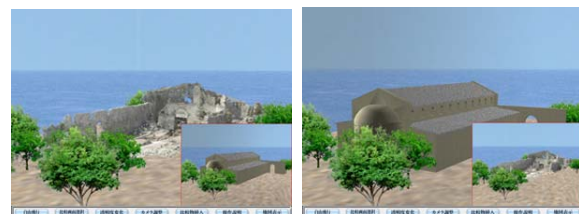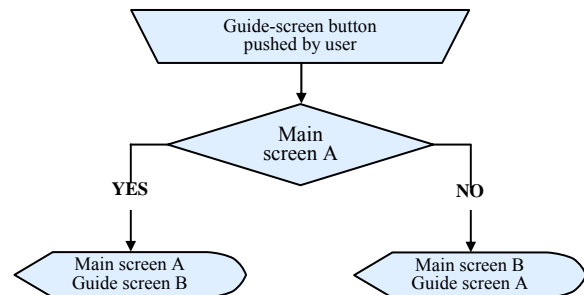

**Figure 10. Two-screen comparison with guide screen**

3.1.3.3 Four-screen mode

● *Photograph/model comparison*: The user can select a photograph from a photograph database (Figure 11, left), and the selected photograph is displayed in the lower left space (Figure 11, right). At the same time, models with the same viewpoint as the photograph can be displayed in the two upper spaces. Using this function enables the user to simultaneously compare the contents of various media, such as a 3D model of an excavation site, a 3D model of the restoration, and a photograph of a particular spot. It also makes it possible to position the camera at a particular viewpoint.

Figure 11. Photograph/model comparison

3.1.4 Cross-section view function

The user can display a cross-sectional view of a structure by controlling the cutting plane, as shown in Figure 12. Using this function enables the user to understand the inner structure in detail.
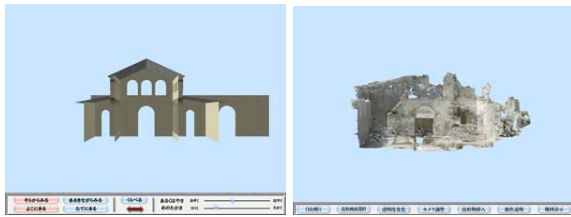
Figure 12. Cross-section viewing function

4. Prototype testing

We tested the prototype system during NICT's open house days in July 2004 and July 2005. The system was used by a total of 134 persons. The interfaces available were a keyboard, a mouse, a game controller, and a space traveler. Each user selected the one easiest for him or her to use. Next, like a person visiting a museum or cultural heritage site, the user was able to freely walk around in a 3D virtual space and experience a cultural heritage site. As the user freely walked through the 3D archives, the system provided comparative views of related content. For example, the user could experience the contents from a different time on the same screen.

Our prototype system worked smoothly, and the users could easily operate the navigation system. The children especially preferred using the game controller and were able to easily master the system, approaching it as if they were playing a game. They thus were able to experience the cultural heritage.

The users made several useful suggestions. For example, some suggested including more detained explanations text would enable them to learn more, thereby enhancing the experiencing of a cultural heritage site using our navigation system.

Figure 13. Photographs of users during open house

5. CONCLUSION

In conclusion, as the first step in developing a shared 3D environment that enables users to interact and understand architectural 3D models collaboratively, we have developed a prototype of an interactive navigation system that supports comparison. We have thus prepared the basic technology for experiencing architectural spaces by quickly examining designs through the Internet. Our comparative navigation system equipped with a 3D database makes it possible to use 3D data and comparison functions for various purposes in

architectural design. Furthermore, the interactive interface built into the real-time rendering system enables a knowledge-exchange architectural design system to be developed, thus providing alternatives to traditional architectural design systems. By using this system, users can experience 3D contents comparison by quickly examining contents through the Internet.

Testing at an open house showed that users ranging from children to senior citizens can easily experience digital archives using our prototype system. Our proposed system promotes the use of digital archives and content by enabling users to interact with the archives, thus raising their level of satisfaction. The development of this system has made it possible to use 3D archives for various purposes. This system is thus a crucial academic compilation containing architectural technologies and cultural aspects of historic architectural structures that have previously lacked clear academic definition.

The most serious problem in the development of a comparative navigation system is the need to process more than 700,000polygons for creating a one-frame image. This is not possible with the hardware setup we used, which has a rendering speed of 0.3 FPS. We thus reduced the number of polygons to 100,000, which can be handled by the present hardware. This time, we divided the plane portions from the curved surface portions and used a polygon reduction algorithm to carry out the maximum maintenance of the present form. We also switched to the DirectX® rendering engine. Furthermore, we were able to achieve a rendering speed of 10 FPS by applying LOD and a clipping algorithm.

We plan to develop an improved version of our system as a trial production system. There are several improvements that can be made directly to the prototype system. First, the data format should be changed as VRML is not suitable for huge models of archaeological sites. Formats such as Web3D might be better. Converting the VRML format data into XVL format data would reduce the model size by about 30%. We also plan to enhance the user interface to enable it to handle other types of media. Furthermore, we are considering the development of a general-purpose function to support access to various types of 3D digital archives. In connection with this, additional 3D digital archives need to be created. Finally, we intend to develop tools that support an expression technique with sufficient reality and that limit the increase in the amount of data and to develop a system that enables smooth cooperation with the database.

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