



VIRTUALIZATION OF REAL-WORLD ASSETS

Integrated research and application of multiple approaches

Lappeenranta–Lahti University of Technology LUT

Bachelor's Programme in Software and System Engineering, Bachelor's thesis

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Jiayao Liu

Examiners: Ari Happonen, D.Sc. (Tech)

Xiaobo Bi, Ph.D.

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

School of International Education

Software Engineering

In co-operation with partner university: Lappeenranta–Lahti University of Technology
LUT

Jiayao Liu

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This thesis research detailed discuss how real-world assets convert into digital assets by using virtualization. By analyze many technologies, including blueprint conversion, 3D scanning technology and artificial intelligence (AI) modeling tools, I explore the application and results of creating assets virtualization of these technologies. In the blueprint conversion aspects, mainly described how to convert architectural blueprint into 3D models by using BIM technology to manage medical facilities. For the 3D scanning technology, mainly discuss using photogrammetry and laser scanning generate high accurate digital twins in the museum. In addition, the thesis also detailed describe AI modelling tools, discussing how the Point-E systems generates detailed 3D models from text prompts, and how the Monster Mash systems can be used to quickly create animated 3D models from 2D sketches. At the same time the paper assesses the strengths and limitations of each technology and suggests possible improvements based on these limitations. These analyses not only reveal the current status and potential of each technology in virtualizing real-world assets, but also point to possible directions for future technological development

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SYMBOLS AND ABBREVIATIONS

Abbreviations

AI	Artificial Intelligence
AR	Augmented Reality
ARAP-L	A Rigidity-preserving, Layered Deformation Model
BIM	Building Information Modelling
CAD	Computer-aided Design
GAN	Generative Adversarial Network
GPU	Graphics Processing Units
IK	Inverse Kinematics
IVE	Immersive Virtual Environment
MLP	Multi-layer Perceptron
NeRF	Neural Radiation Field
SDF	Signed Distance Field
SDS	Score Distillation Sampling
SVD	Singular Value Decomposition
VR	Virtual Reality
3D	Three-dimensional

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1 Introduction

Under the influence of the complex and changing global economic situation and COVID-2019 (Fakieh & Happonen, 2022), the social life and production mode have encountered unprecedented challenges, and as a typical field of integration and innovation of new-generation information technology, virtual reality (VR) and augmented reality (AR) usher in new opportunities (Ghoreishi & Happonen, 2022). With the development of these technologies, there has been a great interest in creating realistic and richly diverse scenes and objects in virtual environments, and they have become concerned with effectively digitizing objects that exist in reality. By converting real-world assets, such as a room, a house, a building, an airplane, into virtual forms of objects and places, we can not only manage and utilize these assets more efficiently, but also open new prospects for applications in a variety of fields, such as education, architecture, and entertainment (Metso & Happonen, 2023; Kinnunen et al., 2019). For example, specific examples of technology applications in the real estate, aviation and entertainment industries and their impacts are shown in detail in table 1. These applications not only bring innovative impetus to related industries, but also greatly promote the application and development of new technologies.

Table 1. Applications of real-world asset virtualization across various fields

Field	Application	Impact
Real Estate	Virtual tours for potential buyers	Improves the convenience and security of transactions
Aviation	Simulated flight training using virtual models of airplanes	Enhances pilot training efficiency and safety
Entertainment	Conversion of real-world scenarios into backgrounds for games and movies	Brings innovative impetus to related industries and fosters technological advancement
Industry	Real world mass customization	Development of 3D printing and unique need based and special equipment and assets

In this background, the study of how to effectively convert real-world assets into their virtual counterparts is not only a demand for technological innovation, but also an inevitable trend of socio-economic development. It is because of the potential of these technologies and the needs of the industry that I have chosen this topic as my thesis. This thesis research will explore how to realize the virtualization of real-world assets. With the research work, the thesis will answer and cover this question by delving into three main technologies: blueprint conversion, 3D scanning technology, and AI modelling tools. The findings of the thesis research provide lots of practical methods and skills. It can convert real-world assets such as houses into 3D models, which help people manage and use these assets.

The whole process contains combining multiple technologies. For example, Autodesk's Revit and 3DS Max can convert architectural blueprints into 3D models (3D Horse, 2018). Unreal Engine and Unreal game engine provide a virtual environment that users can explore. For 3D scanning technologies, photogrammetry can be used to create digital twins for real-world assets, which can be used in VR and AR (McMillion & Hanaphy, 2023). AI technologies such as OpenAI's Point-E and Google's DreamFusion, can create 3D models according to text or voice descriptions, which makes design and modifying models simpler (Wodecki, 2023). Additionally, properly digitalized models can be used for re-editing of the models to be feed into real life asset production flows. For example, using additive manufacturing and 3D printing methods (Widmaier et al., 2013), a physical item without drawings or re-manufacturing instructions, can be duplicated and even enhanced (Piili et al., 2013), with visualization and cost efficient (Piili et al., 2015) 3D printing technologies.

This thesis research provides insights into the process of converting real-world assets into their virtual counterparts. The background and purpose of research on asset virtualization are first presented, highlighting the importance and current state of research in this area. Subsequently, by exploring the specific processes by which different technologies enable assets to be converted into virtual assets, I analyse in depth the application of the various methods and summarize the strengths of the different methods. In addition, the best methods for virtualization of real-world assets are provided for the needs of different development teams based on budgetary constraints. The summary part of the thesis summarizes the main findings and perspectives, provides an in-depth analysis of the application of these three techniques to the virtualization of physical assets and their limitations, and suggests possible directions for improving these techniques in the future.

2 Literature Review

Nowadays, there are many ways to achieve virtualization of real-world assets, and some of the familiar ones are 3D modelling, AR (Tatenda et al., 2023) and VR technology, digital twin technology, blockchain technology, and virtual simulation. Of these, 3D modelling can be categorized into 3D scanning techniques, blueprint conversion and AI modelling tools, which create accurate digital copies of objects (Piili et al., 2013). AR and VR technologies provide users with an enhanced sense of reality and a fully immersive virtual experience, allowing them to explore and operate in a fully virtualized environment. Digital twin technology also monitors, analyses and predicts the performance and maintenance needs of assets by creating real-time digital copies of real-world assets. Blockchain technology uses blockchain to record the ownership and history of assets, ensuring that data cannot be easily tampered with and that there is a high degree of transparency. In addition, virtual simulation mimics the physical and chemical properties of assets in a virtual environment and is widely used for product testing and research. At the same time, there are also links between these technologies, such as 3D scanning software data can be converted into blueprints, digital twins can be used to create digital copies of information from 3D scanning software or blueprints, 3D models can be used for virtual tours in VR or overlaid on actual scenes in AR applications, and so on. The combined application of these technologies not only makes asset management more efficient, but also provides a rich user experience and new application areas, such as virtual tours and distance learning.

This chapter covers three key techniques in the virtualization of real-world assets, the practical application of blueprint conversion, the development of 3D scanning technology in different industries, and how AI modelling tools can generate 3D model generation and digital twins. These three methods were chosen for the study for several reasons. First, they are highly generalized and are techniques that one can easily be able to think of when considering the virtualization of real-world assets. Second, they have a wide range of application cases and mature technical support, closer to our daily life and a wide range of application scenarios and can solve some real-life problems that will be faced, such as the simulation of the visit before buying a house. This makes the research results more reliable and universally applicable. Finally, these three techniques complement each other in that they can work together to create more complete and detailed virtual assets.

In order to demonstrate the progress and applications of these technologies, I have summarized several representative research cases. For example, Autodesk's BIM technology (2021) in the healthcare industry demonstrates how digital modelling and spatial management can improve efficiency and streamline the CMS reimbursement process, reflecting the collaboration between specialized software and the needs of the industry. Neo et al. (2021) in "Frontiers in Virtual Reality" explored the impact of immersive virtual environments (IVEs) design on human behaviour. Campbell and Fraser (2019) investigated the impact of physical activity on the player experience in virtual reality games by developing the VeRitas game. In terms of 3D scanning technology, in the work done by Haleem et al. (2022) highlights the key role of 3D scanning technology in realizing the transformation of Industry 4.0. Daneshmand et al. (2018) reviewed various 3D scanning technologies such as structured-light scanning in the comprehensive survey for 3D scanning technology. The results of the structuredlight scan are shown in Figure 1. Daneshmand et al. (2018) study showed how these technologies adapt to different application requirements. By comparing various scanning approaches, their study highlighted the development of these technologies in terms of achieving more precise asset visualization. Konstantakis et al. (2023) proposed a method. If people want to create accurate digital twins for museum exhibitions, they can choose to use this method. For the application of AI modelling tools, the GET3D models developed by Gao et al. (2022) can generate complex 3D meshes from 2D images. Nicho et al. (2022) developed the Point·E system. It showed a quickly generated process from text prompts to 3D point clouds. Finally, the DreamFusion technology was developed by Poole et al. (2022) showed an innovative generation way that generates 3D models based on text prompts. In addition, the open-source software Monster Mash (2020) provided a novel modelling and animation tool based on the sketches. It allows users to rapidly draw outlines, inflate them to 3D models, and animation. This way simplifies user interaction and the process of accelerating creation. These modelling tools reflect the progress of AI technologies for understanding and creating complex forms.

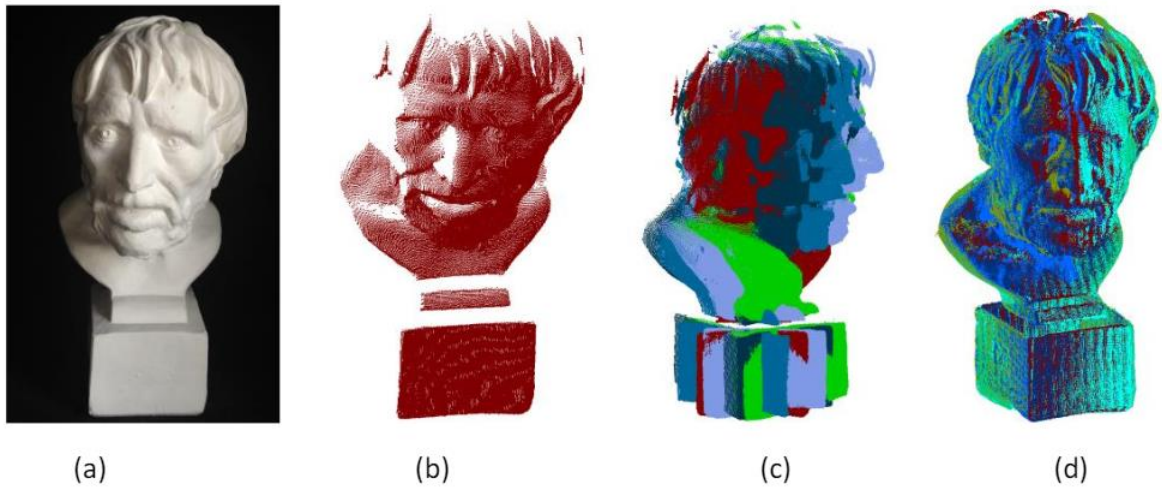


Figure 1. Structured-light scanning results using a turntable: (a) object photo, (b) single scan, (c) multiple scans (different colors), and (d) output model aligned with calibrated turntable axis.

This literature not only reveals the progress of one single technology but also shows the cooperation among different technologies. It helps people to understand how virtual technologies interact with each other and work together to promote the development of real-world assets virtualization and provide new ideas and solutions for it.

3 Research Methodologies

In order to comprehensively assess the technological maturity and application scope of real-world asset virtualization, this thesis research employs the following three main methods: literature review, case studies and comprehensive analysis. These methods will be processed in the next sub-chapters.

3.1 Literature review

An extensive literature collection was first conducted. Several various academic studies and industry reports related to blueprint conversion, 3D scanning technology, and AI modelling tools were selected through the use of academic journal literature portals such as (https://lut.primo.exlibrisgroup.com/discovery/search?vid=358FIN_LUT:LUT) LUT Primo and (<https://scholar.google.com/>) Google Scholar. The scope of the search was not limited to a specific literature or period of time, but rather materials that reflect current technology trends and challenges were selected to build a basic understanding of the current state of the industry and technology development.

3.2 Case studies

For each technology (blueprint conversion, 3D scanning technology, and AI modelling tools), a total of four case studies were selected for research, i.e., BIM technology, 3D scanning technology in a paleontological museum, Point-E system, and Monster Mash tool. The selection of these four cases for the study and not others is based on several key considerations. Firstly, the four selected cases come from the healthcare industry, cultural heritage preservation and creative design, areas that require a high degree of technical precision and data processing. Secondly, the four cases provide insights into how technology can be applied to innovative areas. For example, the application of 3D scanning technology for paleontological museum exhibits is one of the more innovative areas, the Point-E system demonstrates how complex 3D models can be generated from complex textual prompts, and the Monster Mash tool allows users to quickly create animated 3D models from simple 2D

sketches, all of which reflect technological innovation. Finally, these four cases reflect the maturity of different technologies and how they perform in practice. These specific cases provide an in-depth understanding of the specific effectiveness of different technology implementations and assess their effectiveness and limitations in real-world environments.

In short, these cases may be more focused on demonstrating the best practices of specific technologies in particular industries or applications. For example, BIM technology is focused on the healthcare industry, while designing IVEs and enhancing the experience of virtual reality sports gaming uses blueprint conversion, which converts two-dimensional images into virtual environments, and both papers are more focused on the combination of blueprint conversion and VR technology rather than blueprint conversion alone. As well as three literatures about 3D scanning technology, through searching the literatures I found that a large part of 3D scanning technology is applied in museums, and two of the literatures are more inclined to the comprehensive analysis of 3D scanning technology, so I chose the application of 3D scanning technology in paleontological museums as my research object. In addition, for AI modelling tools, the Point·E system and Monster Mash tool are chosen as the main research objects instead of GET3D generating model and DreamFusion technology. First, the Point·E system uses direct 3D model generation from complex text descriptions, providing flexibility and high speed for rapid prototyping and virtual reality content creation. The Monster Mash tool, through its intuitive interface, allows users to quickly generate animated 3D models from 2D sketches, dramatically lowering the technical threshold for 3D modelling. In addition, although the sample quality of the Point·E system needs to be improved, it is showing that there is significant room for improvement and optimization of its technology in the future, which provides an opportunity to study how to overcome the existing limitations and advance the technology. Meanwhile, the Point·E system combines advanced technologies from several AI fields, such as natural language processing, computer vision and machine learning, which not only broadens the path of interdisciplinary research, but also meets the market demand for fast and flexible 3D content generation technologies. And the Monster Mash tool demonstrates an innovative application of 3D modelling technology by supporting direct conversion from sketches to animated 3D models, enhancing the usefulness of this technology in creative expression.

Thus, choosing these four cases over the other six allows me to focus more on demonstrating best practices of different technologies in specific industries, whereas the other six cases

relate to broader underlying research. Such a choice is a strong argument for the technological maturity and usefulness of virtualization of real-world assets. In particular, the selected cases demonstrate the application, benefits, and challenges of the technologies in practice, in order to provide an in-depth understanding of the operational details and real-world performance of each technology.

3.3 Comprehensive analysis

Finally, an analysis of the overall performance of each technology is conducted, which combines quantitative data and qualitative feedback for evaluation. Quantitative data includes metrics such as the accuracy of model generation, while qualitative feedback is derived from user evaluations of aspects such as the ease of use of the technology. This analysis helps to reveal the strengths, limitations, and applicability of each technology to the population.

In summary, in this research, I used three to comprehensively assess the maturity and application of real-world asset virtualization technologies. By combining these three approaches, I discuss in depth the performance as well as the strengths and weaknesses of each approach in practical applications. At the same time, the combination of quantitative and qualitative analyses further deepens the understanding of these techniques and provides a small contribution to the best practices and future development of real-world asset virtualization.

4 Case Studies

In this chapter, I will explore in detail the specific ways in which these four techniques can be used in specific application areas. Specifically, I chose four cases in three different applications to study, which are the applications of BIM technology in facilities management, the applications of 3D scanning technology in preservation of cultural relics and the applications of two AI technologies in different areas. The analysis process contains the implementation process of the technologies, effects in actual applications and the advantages and challenges of the technologies. Of these, the BIM technique and the 3D scanning technique could not be tested. Firstly, the BIM technology involves the use of Autodesk Revit software. This software requires professional knowledge and expensive license fees. Because I don't have right to use this software, I can't use it to test BIM technology. In addition, testing BIM technology may need access to specific project files or data which generally are protected by copyright and privacy, so I can't access them. In addition, 3D scanning technology needs to rely on professional scanners to capture 3D data of objects or scenes. These scanners are often expensive and operators need to have superb knowledge. This causes that I can't test 3D scanning technology. 3D scanning may involve processing software, which also has specific licenses and technical support. Therefore, I have to rely on existing literature to analyse these techniques. By analysing related literature, I can know the principles, use cases, advantages and disadvantages of these technologies and the effects in actual environments, instead of directly operating these technologies.

As I described in Section 3.2 in the third chapter, I chose these the four cases because they highlight their advantages and challenges in practical applications, demonstrating the maturity and usefulness of these technologies. Therefore, I will focus on the application of BIM technology in healthcare facility management, the practical application of digital twins in paleontological museums, how to convert textual descriptions into detailed point cloud data using the Point-E system, and the creation of animated 3D models using the Monster Mash tool. Detailed application descriptions of these four technologies are given below.

In addition, since I did not actually test the first two techniques, I analyse the effectiveness, advantages and challenges of BIM technology and 3D scanning technology through the literature review. The literature shows that BIM technology can effectively manage medical

facilities and 3D scanning technology shows high efficiency in the protection and research of exhibitions aspects.

4.1 Application of BIM technology in healthcare facility management

Autodesk Revit software is utilized to generate a computable 3D model of the building, which contains all the building elements such as walls, windows, doors, pipes, etc. These elements not only have corresponding geometries, but also associated data such as material information, cost and maintenance information. The model contains information from different engineering departments, such as 3D model views and 2D floor plans, ensuring that all information is always consistent. For example, if the position of a window is changed, the change will be updated to all affected views, i.e., the relevant floor plans and area schedules are automatically updated. This reduces errors and information redundancy and ensures accurate reporting.

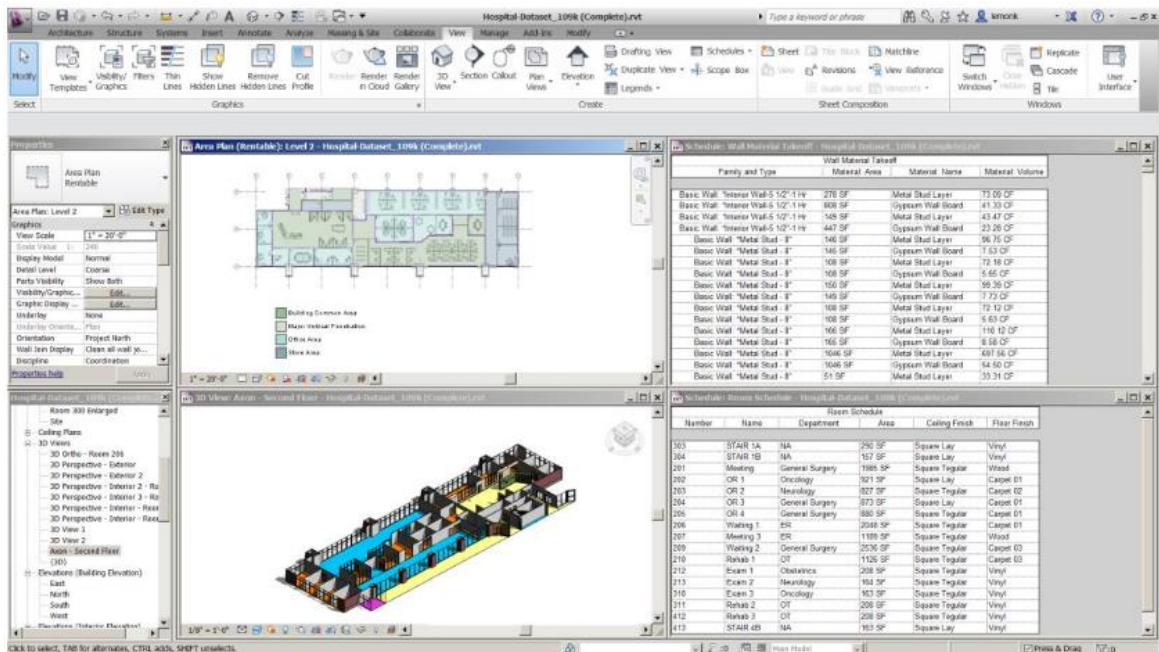


Figure 2. Intelligent areas in the Revit building model simplify the definition and calculation of spatial relationships.

Additionally, Revit has intelligent area features for defining spatial relationships and streamlining spatial calculations and reporting (Figure 2). It updates area calculations in real time for greater efficiency and precision than traditional manual area measurement methods and CAD applications. It allows the user to set up spatial relationships and intelligent area elements and floor plans according to specific needs, automatically generates area boundaries and updates area calculations in real time.

It has the following features in Revit modelling. The first is the automatic generation of area boundaries and automatic calculation of area sizes. The user selects model elements and automatically generates area boundaries that remain connected to the underlying model elements (walls, ceilings, etc.). Second, the area boundaries are automatically adjusted according to industry standards (e.g., ANSI/BOMA) to calculate the area. For example, the gross floor area is calculated based on the outside of the walls, while the office area is based on the inside measurement of the walls. Additionally, if a window's height is more than half the height of the wall, the area boundary is adjusted to the window glass surface instead of the inside of the wall. If the height of a window is modified to be less than half the height of a wall, then the area boundary is brought back to the inside of the wall and the area is automatically updated. Third, Revit allows users to set a departmental parameter for each area and create area color schemes based on the parameter. This allows the facility manager to visualize how different departments are distributed in the building. These color-coded floor plans are automatically updated when the building model changes, eliminating the need for manual modifications. Fourth, it allows facility managers to view area information in tabular form. This area form is more efficient and accurate than traditional manual or CAD methods. Facility managers can easily create various types of forms as needed, such as building interiors forms. The information in these forms is updated in synchronization with the underlying model to ensure accuracy. These forms can be easily added to any drawing paper or floor plan, or exported to common spreadsheet formats for team sharing or further processing.

4.1.1 Effectiveness of BIM technology

BIM technology not only creates a static 3D building model, but also implement a dynamic, interactive asset management system. The model contains all the necessary architectural and

spatial information, such as room sizes, room elements, and so on. The use of this technology ensures that all building space records are based on the most up-to-date and accurate information, and that changes are automatically updated in all relevant documents, making it easier for healthcare facility managers and designers to accurately assess and implement design and space changes, reducing the duplication of effort and human error associated with the traditional space management process (manually mapping and measuring space), and streamlining space reporting, which is critical to meeting the stringent requirements for CMS reimbursement.

4.1.2 Advantages of BIM technology

Increased accuracy of documents and calculations: The documents and calculations used by facility managers are much more accurate when dealing with day-to-day activities and making annual cost reports, and the automated change management feature ensures accuracy and quality, which directly impacts the accuracy of CMS reimbursements, which can potentially increase reimbursements for hospitals by nearly a million dollars per year.

Time and cost savings: Space management using BIM can be accomplished faster than traditional CAD methods and does not need to be implemented manually; all calculations and documentation are automatically generated and always updated in synchronization with the 3D model, increasing productivity while reducing errors.

Enhanced decision support: With high-quality visualization tools and models, facility managers can present and evaluate space configuration options more clearly and easily, supporting more informed decisions.

4.1.3 Challenges of BIM technology

High-cost initial investment: BIM technology can be cost-saving in the long run, but early in the project, organizations need to invest a significant amount of money, including software costs and training costs.

Technical training: Employees need to accept specialized training in terms of BIM technology so that they can fully understand and use it. In the initial implementation, there

may be problems with employees being unable to adapt. Therefore, it needs extra time and resources to deal with problems that arise from this need.

Data management: Ensure data has high accuracy and consistency. If data is wrong or inconsistent, the time and costs of the project will increase.

4.2 Digital twins in a paleontological museum

The whole process can be roughly divided into the following six steps (Figure 3), which is sourced from the paper by Konstantakis at al. (2023).

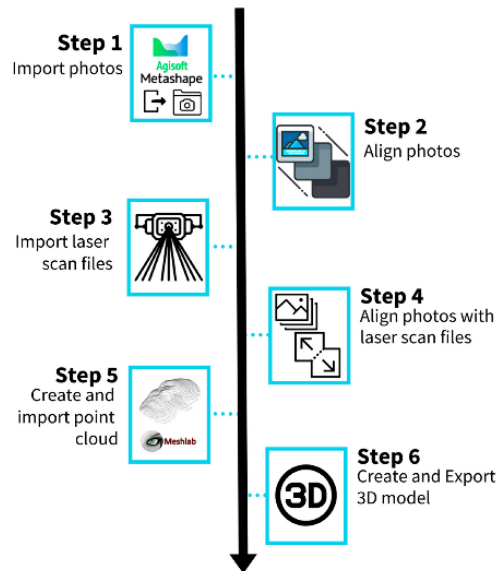


Figure 3. The whole methodology of creating digital twins for paleontological exhibits

First, the research team used Agisoft Metashape software to process all available photos taken with a professional camera or smartphone and grouped them according to the shooting device, angle and time of day to optimize the subsequent photo alignment process. It may be complicated by changes in camera position, weather or light at the time of shooting. Therefore, we need to adjust many settings in the software to ensure that all photos are accurately aligned. Laser scanners such as the FARO M70 and Scan-in-a-box (Figure 4) create extremely accurate 3D point clouds, often requiring multiple scans of each exhibit to cover all the details. These point clouds were then aligned in the scanner software before

being imported into Agisoft Metashape at the origin point coordinates. It is important to note that the photos must be aligned with the laser scan data, which is a critical stage in the process. And different settings and resolutions were tested to ensure that the data from the different methods would fit together perfectly.



Figure 4. Scanning of fossil coral colonies with Scan-in-a-box structured-light scanner.

After summarizing the photos and point clouds, Meshlab software was used to further process the data. Unlike Agisoft Metashape, Meshlab is used to optimize the final point cloud, including reducing the number of polygons, removing erroneous points or filling in possible gaps, reducing the file size and point density, and making the final file more suitable for viewing on a phone or other mobile device. Eventually, the point clouds data are converted into a 3D model and saved in a specific format (obj or stl format) (Figure 5). This comes down to a small model with only a few thousand data points to a large model with millions of data points in the final 3D model.

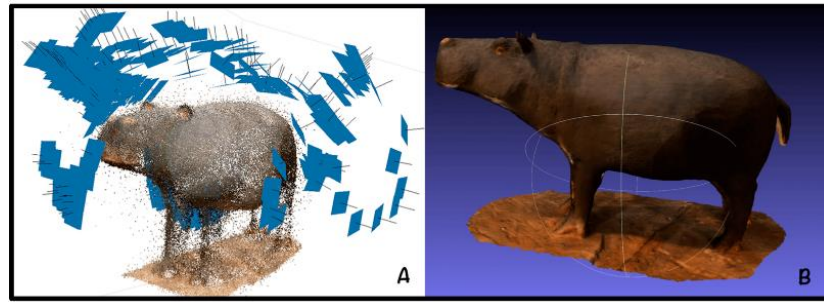


Figure 5. An example of a 3D model of the final fossilized pygmy hippopotamus, with A textured and B untextured.

This process roughly demonstrates how real paleontological exhibits can be transformed into a 3D digital model ready to be viewed and studied on a computer that is not only visually accurate, but also contains a wealth of detail for a variety of digital applications. For example, we can clearly see the true color and material of the 3D model of the final fossilized pygmy hippopotamus, and tiny particles on the surface of the exhibits, even the details and deep pitting of the skin.

4.2.1 Effectiveness of 3D scanning technology based on camera image and laser

This technology can create precise digital models of artifacts or buildings. It plays an important role in restoring, studying and showing of artifacts or buildings. And it not only brings convenience to research but also greatly helps the development of education and entertainment, even brings a novel experience to visitors.

4.2.2 Advantages of 3D scanning technology based on camera image and laser

High-precision models: This technology can accurately show every detail of the scanned objects. For some complex and delicate artifacts, it's difficult for people to use their eyes to clearly see the details, but this technology can do it because its precision can reach the micron level. Specifically, high-precision 3D scanners can achieve an accuracy of 5-30 microns. This means that under this technology, the 3D models of artifacts produced can accurately reflect their details.

Reduced damage to artifacts: This technology doesn't need to physically handle or touch with the original object, so it's applicable for those fragile or precious artifacts.

Support for model backup and sharing: The created models can be used for education, study and display, and also be backed up. Therefore, when the original objects are damaged or lost, this backup is important. Meanwhile, these models can share on the Internet, so as to improve cultural communication with different countries.

4.2.3 Challenges of 3D scanning technology based on camera image and laser

High equipment costs and maintenance: Advanced 3D scanners usually have a high price. And the operators need to master professional technical knowledge to operate and maintain such equipment. Therefore, in a resource-limited environment, high costs may become the major problem for using this technology.

Have professional knowledge: The operator needs to have advanced technical knowledge and experience, including proficiency in using scanners and the ability to process and analyse data. In addition, incorrect operation and data processing may cause inaccurate scanning results.

Data storage and security: The amount of data generated by this technology is very large, and the research team needs to have a high-performance data storage and management system. At the same time, the issue of data security and sustainability is also a key, especially for digital assets that have irreplaceable historical value.

Multiple factors: The effectiveness of 3D scanning is affected by a variety of factors, such as dim lighting, very high humidity in the space or artifacts in inaccessible places, which exacerbate the difficulty of scanning or the accuracy of the results. The reflectivity and transparency of certain materials may also limit the accuracy of the scan, making it difficult to get a high-quality scan of objects that are transparent or highly reflective, for example.

4.3 Converting text prompts into point clouds using Point-E system

4.3.1 Description of the method

This study converts text descriptions into point clouds in the following main steps:

- 1) Generate a synthetic view based on the textual description using an adapted GLIDE model (Nichol et al., 2021), which is fine-tuned on the rendered 3D model dataset.
- 2) This synthetic view is used to generate a rough point cloud containing 1024 points. This step uses a conditional (dependent on the given synthetic view to generate the data), arrangement-invariant (the output of the model (the point cloud) does not depend on the order of the input points) diffusion model. The Transformer model is used as the main prediction mechanism in this process. It first processes the noised input x_t with random noise through a linear layer, through which the raw features of each point (e.g., coordinates and color) are transformed into a tensor with a D -dimensional output. In addition, the model also processes the time step t , which is processed through a small multi-layer perceptron (MLP) to produce another D -dimensional vector. The D -dimensional vectors of these two types of data are integrated into the context of the Transformer model. The integrated data allows the Transformer model to process this noise using its self-attentive mechanism, gradually removing the noise and accurately predicting the final position and color of each point. In this way, the model effectively transforms x_t , which contains random noise, into a sharper and more accurate 1024-point rough point cloud, which lays the groundwork for the subsequent generation of a higher resolution point cloud.
- 3) Combine this low-resolution point cloud with the synthetic view to produce a fine point cloud containing 4096 points. A smaller diffusion model is used here, which additionally relies on the low-resolution point cloud to improve the resolution and quality of the point cloud. In addition, another Transformer model is used here. It also starts with processing each point from a low-resolution point cloud (1024 points) through a linear layer to transform its features into a tensor with D -dimensional output. In addition, the time step t of this stage is also processed through the same small MLP to generate a D -dimensional vector. These feature vectors and time step

vectors of the points obtained from the low-resolution point cloud are again integrated into the context of the Transformer model. At this point, the model not only reevaluates and adjusts the features of the points already present, but also predicts additional points to form a more detailed point cloud totalling 4096 points. The integrated data allows the Transformer model to refine the position and color of each point, ultimately producing a high quality and high-resolution point cloud.

- 4) Finally, a regression-based model is used to predict the Signed Distance Field (SDF) of the point cloud before the Marching Cubes algorithm is used to "draw" a smooth outer surface around these points based on the distance values, ultimately forming a complete, continuous mesh. The colors of the mesh vertices are aligned with the colors of the points in the point cloud closest to that point.

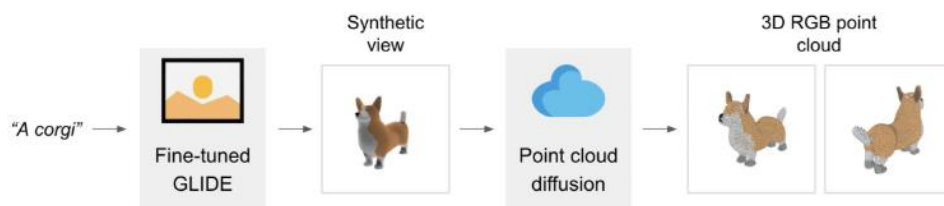


Figure 6. Approximate process of text prompts to generate 3D models.

The approximate process of the first three steps is shown in Figure 6. There are some details in it. For example, in terms of data processing, the research team trained on millions of 3D models. In order to convert all data into one type, the researchers rendered these models from different camera angles into RGBAD images and then used Blender software to render. These images would be converted into colorful point clouds. Ensuring the uniformity and quality of point clouds by optimizing and using heuristics to further filter datasets, such as using Singular Value Decomposition (SVD) to remove unsuitable models or using CLIP features to cluster data. In this way, the research team could create complex datasets that can be used as training deep learning models. This accurate data processing ensures high quality and precision of the conversion process from texts to 3D models and improves the performance and output quality of the whole system.

4.3.2 Testing of the Point-E system

To effectively test the performance and accuracy of Point-E technology and ensure every generated result looks like the text description, I designed these detailed testing processes.

1) Installation and environment setup

- Install Python 3.6 or later.
- Run “pip install -e .” to install Point-E and its dependencies.
- The NVIDIA T4 Tensor Core GPU is used as a hardware accelerator, T4 GPU is a type of Graphics Processing Unit (GPU) that is applicable to accelerating machine learning, AI and high-performance computing tasks. Because it provides the necessary computational resources without over-consuming costs, it is suitable for handling medium-sized computational tasks and is suitable for the initial development and testing phases.
- Run `text2pointcloud.ipynb` to check that the Point-E environment is set up correctly and to ensure that a 3D point cloud can be generated from a text description. This notebook is specifically designed to generate 3D point clouds directly from simple text descriptions, and although the model quality is low, it can handle some base classes and colors.

2) Prepare a test dataset

First, a test dataset with multiple text prompts with explicit descriptions is prepared to ensure that object descriptions of different types, colors, and features are covered in order to test the model's ability to generate in a wide range of scenarios. When confirming this test dataset, I made careful considerations and filters instead of picking them randomly. I hope the dataset is close to our life, so I selected furniture, animals, objects, and architecture as keywords. Then, to ensure get a various dataset, I thought of some specific objects from each category, e.g., watches, churches, elephants, etc. At the same time, I briefly evaluated the effectiveness of each description to ensure that they guided the model to produce a rich variety of responses. Through these steps, I finally confirmed the dataset. In this test, the test set used contains the following four descriptions:

- “A black leather office chair with adjustable armrests and caster wheels”.

- “An elephant with a long trunk and large ears, covered in a grey skin”.
- “A watch with a silver band and blue face”.
- “A gothic cathedral with large stained-glass windows and a tall spire”.

3) Run the generation process

The generation process was run three times repeatedly for each text prompt to observe the consistency and variability of the generated results under the same text input (Figure 7). In this case, multi-view models are generated by setting different `grid_size` (Figure 8). When the grid size is 3, 9 viewpoints can be generated, which helps to deeply evaluate the details and accuracy of the 3D model. All generated point cloud data will be recorded and saved for subsequent analysis and evaluation.

```
[14] # Set a prompt to condition on.
      prompt = ''

      # Produce a sample from the model.
      samples = None
      for x in tqdm(sampler.sample_batch_progressive(batch_size=1, model_kwargs=dict(texts=[prompt]))):
          samples = x
```

Figure 7. Initial code execution setup

```
pc = sampler.output_to_point_clouds(samples)[0]
fig = plot_point_cloud(pc, grid_size=1, fixed_bounds=((-0.75, -0.75, -0.75), (0.75, 0.75, 0.75)))

pc = sampler.output_to_point_clouds(samples)[0]
fig = plot_point_cloud(pc, grid_size=3, fixed_bounds=((-0.75, -0.75, -0.75), (0.75, 0.75, 0.75)))
```

Figure 8. Point cloud generation with `grid_size` modification

4) Result evaluation

Each generated point cloud is visual examined to assess whether it matches the object characteristics described in the original text, such as type, color, and features. At the same

time, analyse the consistency of the results generated multiple times for the same text description to assess the stability of the model.

5) Analysis of results

The test results are analysed in detail to identify the strengths and weaknesses of the model. Based on these findings, improvement measures are proposed.

4.4 Monster Mash tool

Monster Mash is a sketch-based tool that allows users to quickly create and animate 3D models from 2D sketches. The core technology of the system is 3D inflation and a rigidity-preserving, layered deformation model (ARAP-L).

4.4.1 Method description

In the following I will describe the main processes of both methods.

1) 3D inflation

Monster Mash utilizes 3D inflation to automatically convert user-drawn 2D lines and shapes into a three-dimensional mesh. The process is described as follows:

- Check if the drawn lines are closed. If the lines are not closed, the system automatically closes them to form a complete outline.
- The system adds volume along the vertical extension of each outline to generate the corresponding 3D mesh. Simply speaking, a planar figure is expanded to form a three-dimensional shape.
- The surface of the expanded model may not be smooth or have sharp edges, which are automatically smoothed to ensure that the model looks more realistic and natural.

The 3D mesh generated by this process is the basis for all subsequent operations, so the mesh needs to perfectly replicate the user's design intent, and at the same time have rich details to support subsequent deformation and animation.

2) ARAP-L

Through the ARAP-L technique, the system ensures that the original structure and shape of each part of the model is maintained as much as possible during deformation, thus avoiding unnatural distortions or deformations of the model during the animation process. This method is described as follows:

- This technique is implemented by minimizing the local distance changes of the mesh vertices before and after the deformation. It involves defining an objective function to measure the degree of shape change of each part of the model before and after the deformation, using the positions of the mesh vertices in the deformation as variables, and adding certain necessary constraints, such as the positions of fixed points. Then using the gradient descent method which is a mathematical optimization algorithm to solve these problems, that is, find a set of vertex positions so that the overall change of the models is as small as possible when deforming. The system repeatedly adjusts the position of the vertices, until reaching the best situation, that is, the shape of the models keeps original as soon as possible and vertices move as little as possible so that the animation process looks natural and smooth.
- When making animation, the system ensures the parts of models have a correct order and accurate position through a specific depth and position constraint, avoiding the situation that model parts misplace or cross during animation. If adjusted a part of the models, the system would automatically calculate these constraint conditions to ensure the nature and consistency of the animation.
- With the help of modern GPUs, this system can real-time respond to user operations and immediately show the effects of deformation or animation.

Monster Mash not only provides users with an intuitive and easy-to-use platform, but also by combining 3D inflation and ARAP-L technology, users can quickly create natural and smooth 3D animation models from 2D images.

4.4.2 Testing of the Monster Mash tool

In order to test the performance of the Monster Mash system, I designed a set of testing methods. I designed this process by following the detailed tutorial provided with the Monster Mash platform. I just simply following the instructions in the tutorial, sketching to generating the model and creating simple animations.

- 1) Test preparation: The dataset is divided into two parts, which are uploaded sketches and drawn sketches. Every sketch test two times.
 - Uploaded sketches: Drawing the outline of objects in the picture and the system would automatically inflate a 3D model based on the outlines.
 - Drawn sketches: Drawing the outlines on the drawing board, then the system inflates the 3D models accordingly.
- 2) Animation: Creates simple animations for each generated 3D model, and tries to drag different model parts, such as arms or legs. By testing various animation points, observe the efficiency and results of the system when dealing with animation commands and the smoothness of animation.
- 3) System evaluation
 - Evaluate the ease of use and learnability of the system.
 - Check the visual effects of each generated 3D model and animations if there are any graphics errors or other problems.

I tested the system according to the process described above. This process totally generated 4 animated models (2 uploaded sketches and 2 drawn sketches), and the testing process spent 1 hour running, of which 30 minutes was for drawing, 10 minutes was for the tool to generate the models, and the remaining 20 minutes was to create simple animations for the models. Each model was repeated for 2 iterations to ensure consistency and reliability of the results.

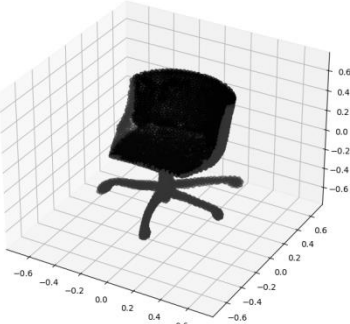
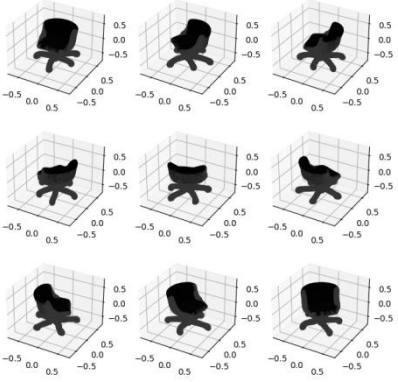
5 Test Results of AI Modelling Tools

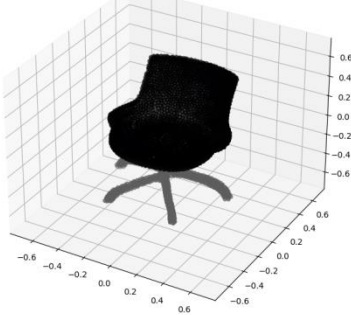
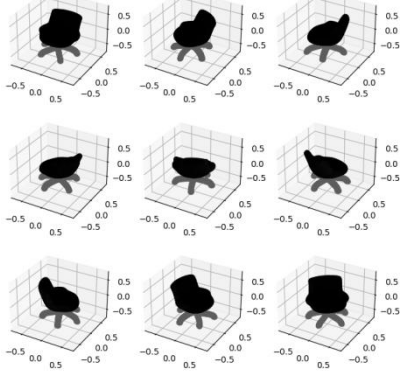
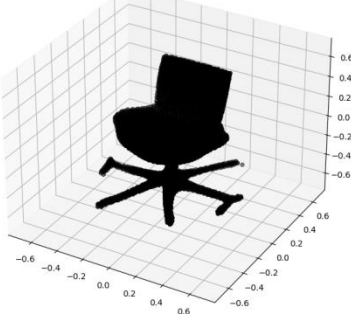
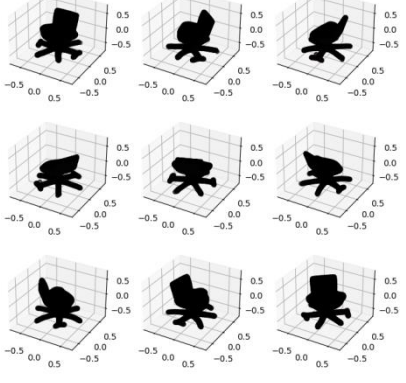
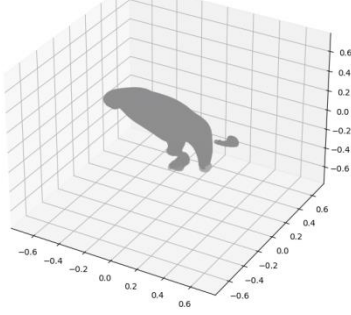
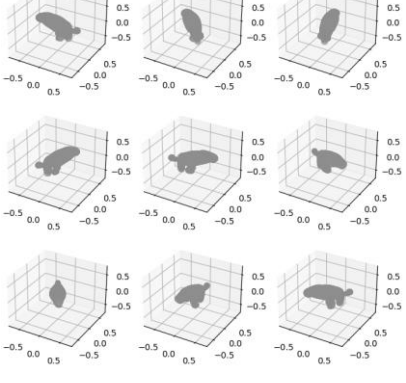
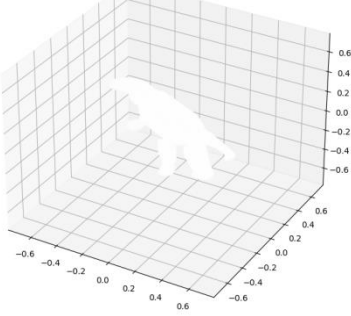
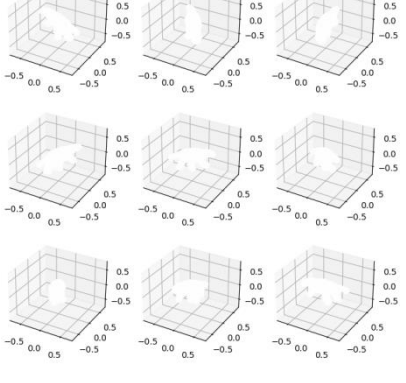
In this chapter, I discuss the performance of the Point-E system and Monster Mash system by using actual tests, so as to verify the real application effects of these new technologies. The test results show that the Point-E system can quickly generate 3D models according to text description and the Monster Mash system provides a simple platform where users are able to convert sketches into 3D animation models. These results not only demonstrate the utility of each technology but also show their advantages and challenges in different applications. My purpose in doing so is to fully evaluate and compare these technologies through practical testing, which can provide reference and guidance for their application in related fields.

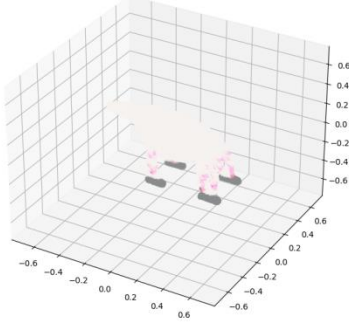
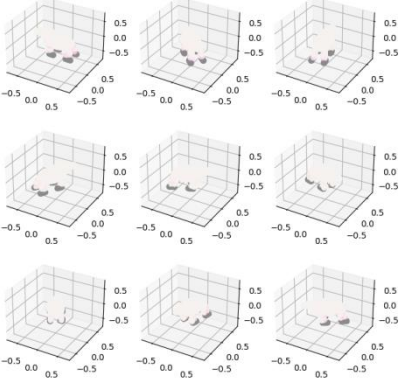
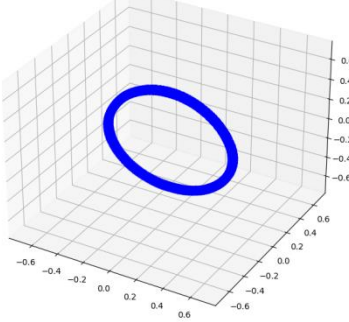
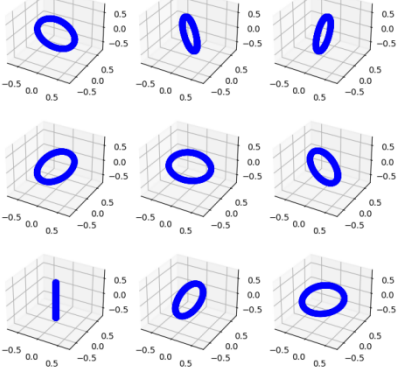
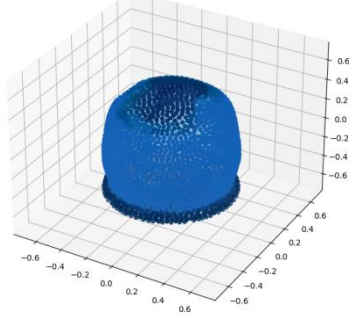
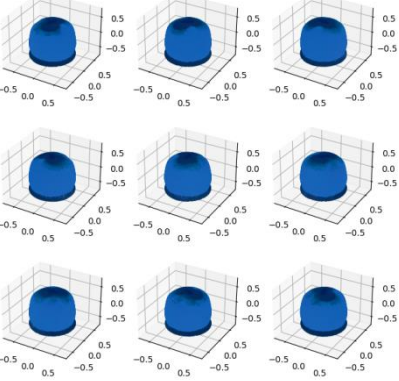
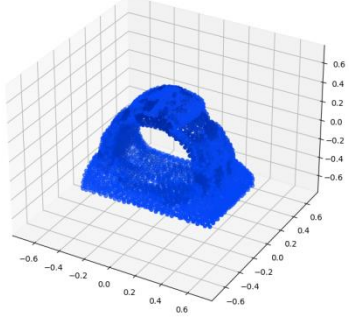
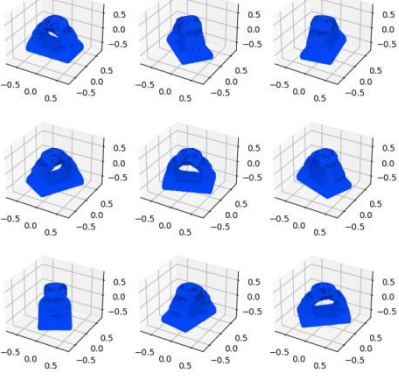
5.1 Point-E system

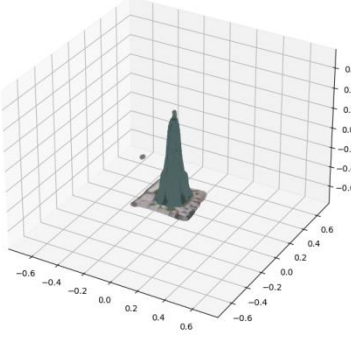
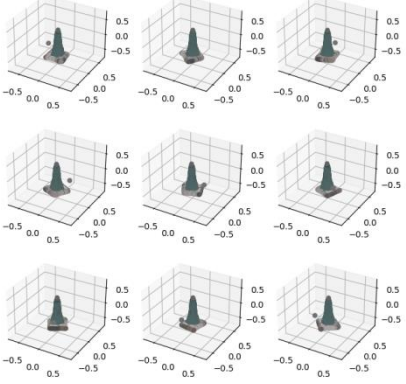
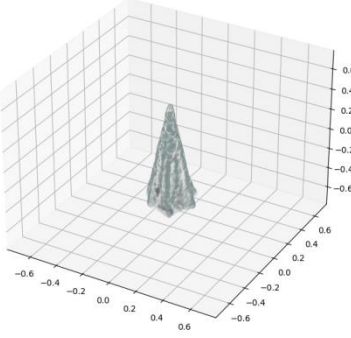
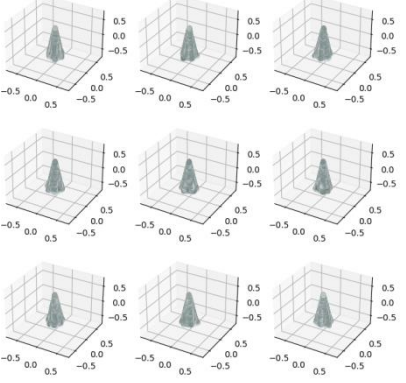
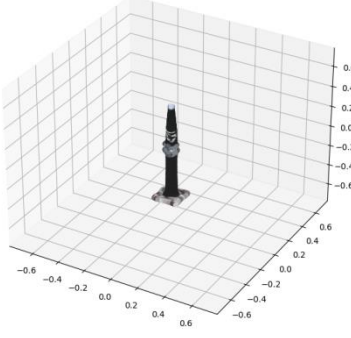
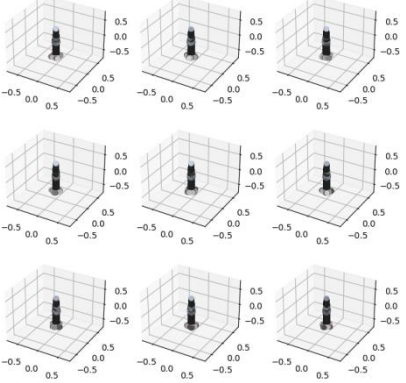
Table 2 shows the results of the test. According to the results, we can see that the Point-E system can directly generate 3D models based on different textual descriptions. The dataset used for the test is more specific in its description and involves different categories of objects such as office chairs, elephants, watches and gothic cathedrals.

Table 2. Summary of object descriptions and iterations

Object Description	Iteration	Results (grid_size = 1)	Results (grid_size = 3)
A black leather office chair with adjustable armrests and caster wheels.	First Iteration		

	<p>Second Iteration</p>		
	<p>Third Iteration</p>		
<p>An elephant with a long trunk and large ears, covered in a grey skin.</p>	<p>First Iteration</p>		
	<p>Second Iteration</p>		

	<p>Third Iteration</p>		
<p>A watch with a silver band and blue face.</p>	<p>First Iteration</p>		
	<p>Second Iteration</p>		
	<p>Third Iteration</p>		

<p>A gothic cathedral with large stained-glass windows and a tall spire.</p>	<p>First Iteration</p>		
	<p>Second Iteration</p>		
	<p>Third Iteration</p>		

5.1.1 Point-E system performance analysis

Generation time: The generation time of each model is between 59 and 64 seconds. The length of the generation time is related to the complexity of the text prompts. For example, for longer and more complex sentences, the generation time is longer, can reach 64 seconds, while for simpler sentences, the generation time is around 59 seconds. It shows that the

Point-E system has a relatively stable time efficiency in processing these more complex text prompts, and really realizes fast generation.

Generation quality: The generation process was run three times for each of the four different text descriptions, and based on the images of the generated 3D models we can see that the detail and accuracy of the 3D models varied each time. This difference indicates that the Point-E system is able to explore different paths of building models in multiple attempts, increasing the diversity of generation.

5.1.2 Advantages of Point-E system

Fast: After choosing the right hardware accelerators (T4 GPUs were used for the tests), the generation of the model is fast. The time is relatively stable for models of different complexity. Therefore, the system is suitable for rapid prototyping and iteration.

Versatility: The system is able to generate different 3D models based on different text prompts, adapting to the needs of multiple scenarios.

User-friendly: Users only need to provide simple text prompts to run the code to automatically generate 3D models. The system is very easy to operate for users.

5.1.3 Challenges of Point-E system

Lack of consistency: The models produced in different attempts with the same text prompt varied significantly. For example, for the description "A elephant with a long trunk and large ears, covered in a grey skin", some elephant models were grey, while others were white.

Mismatch with description: Some generated models do not match the text description. For example, for the description "A watch with a silver band and blue face", the second and third generated models did not look like watches at all. Also, for an office chair that requires armrests, the first and third generated models do not appear to have armrests at all.




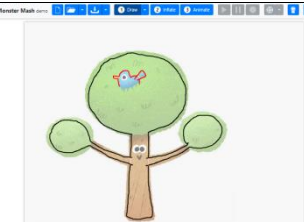

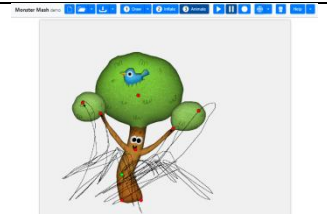
Detail processing problems: Some models are not fine enough, for example, for the description "A watch with a silver band and blue face", the first generated model only has a blue band, which is completely inconsistent with the original description. At the same time,

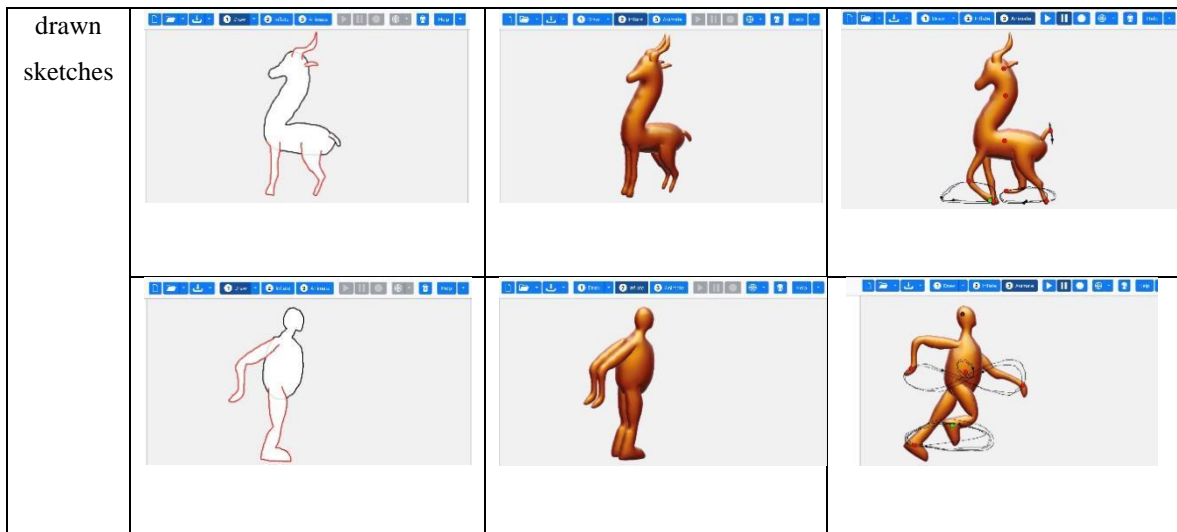
to generate a large-stained-glass windows with a gothic cathedral, these three models do not reflect the "stained" this feature.

5.2 Monster Mash 3D model creation and animation tool

Table 3 shows the results of the test. According to the results, we can see that the Monster Mash system provides beginners and designers with a good interface and functionality for automatically converting 2D sketches into animated 3D models. Two types of input were processed throughout the tests: uploaded sketches and drawn sketches, with two attempts at each. One attempt may not fully reflect the tool's stability and consistency, and even though three attempts could provide more data, the time and resources were limited and the testing results would take up a lot of place, which would be lengthy. Therefore, I chose two attempts for each type of sketch. These tests demonstrated the system's ability to handle different types of sketches.

Table 3. Sketch-to-animation process

	Drawing	Inflation	Animation
uploade d sketches			
			



5.2.1 Advantages of Monster Mash

Low technical threshold: The system allows users to directly upload images or use the platform to draw sketches, lowering the technical threshold for creating and animating 3D models.

User-friendly interface: The entire interface is user-friendly and easy to use for non-specialized users. With simple clicks and buttons, users can get a basic 3D model or an animated model.

Independent deformation control: When one part of the model is deformed, the deformation of that part will not affect the other parts, which helps to control the animation effect of complex models more precisely. For all models, I can individually select and manipulate a part of the model, such as separately controlling two branches of a tree to move in different directions without affecting the position of the leaves. This feature is especially beneficial when creating animations involving multi-jointed movements, where each part can be adjusted individually for a more natural and precise animation.

Rapid generation: The conversion from sketch to model is very fast. For simple outlines, the system can finish model inflation within 2 seconds. For complex outlines, it may need at least 30 seconds. Therefore, this system is ideal for rapid prototyping and creative expression. Especially, it is suitable for simple geometric shapes or basic character designs that do not

require much detail. On the other hand, the tool is not suitable for models that require a high level of detail, such as a realistic character or a part with a complex structure.

Instant visual feedback: The system provides instant visual feedback so that users can immediately see the visual effect of their added animation points, enhancing the intuition and efficiency of the operation.

5.2.2 Challenges of Monster Mash

Operational limitations: The system interface only allows undoing a previous step and there is no way to undo an undone step, which limits the user's flexibility in the editing process.

Drawing challenges: When importing sketches and drawing outlines, the entire outline must be drawn in one stroke without interruption. This rule makes it more difficult to work with, especially when sketching complex or elongated outlines.

Detail-dependent sketches: The detail and accuracy of the 3D model generated by the system is related to the quality of the original sketches, and inaccurate sketches result in a 3D model that lacks detail. For example, the puppy model's face may appear flat and lack expression because it was inflated from a sketch outline.

Basic animation features: Although the system supports the addition of animation points, the animation features are relatively basic and do not meet the complex animation needs of the professional level.

Difficulty with complex shapes: The system may have problems with particularly complex shapes, such as missing model details or parts that are not molded. For example, after sketching the person and generating the corresponding 3D model, and adding animation points for the arm, it was found that the arm and the body overlapped during the animation playback, resulting in the arm appearing to be through-molded.

6 Future Work of the Reviewed Tools

In this chapter, in terms of the challenges mentioned above, I propose a set of specific measures that can be implemented in the future to address these problems to ensure continuous progress and applications. The following are strategies for each technology that can be taken in the future, involving BIM technology optimization, the application of digital twin technology in the paleontological museum, the improvement of Point·E system and the upgrade of the Monster Mash tool. These measures aim to push the development of these technologies and enhance the user experience.

6.1 BIM technology

- Finding financial support: Work with governments or corporations to obtain initial financial support. At the same time, demonstrate the long-term benefits of BIM technology to project investors or find additional investors to obtain more funding.
- Training and technical support: Develop easy-to-understand training courses on BIM technology that employees can participate in through online learning. In addition, a technical support forum can be created to help employees resolve issues encountered during implementation.
- Optimize data management: Adopt AI technology to optimize data management and integration automatically detecting inconsistent data and resolving it to reduce human error.

6.2 3D scanning technology

- Getting more financial support: Get more financial support by first getting initial financial support and showing sponsors the long-term benefits of this approach. And of course, don't forget to try to find more sponsors.

- **Technical training:** To address the technical problems of the operators, professional training courses and seminars can be offered on a regular basis to ensure that the operators can master this technology.
- **Equipment selection:** Priority is given to the most cost-effective 3D scanning equipment, i.e., the most suitable for project development and reasonably priced. Also optimize the data processing software during the scanning process to improve scanning quality.
- **Improve accuracy and applicability:** Improve lighting conditions by using portable light sources and multispectral scanning technology, combined with robotics or telescoping devices to scan hard-to-reach areas. Advanced algorithms are also used to process the data.

6.3 Point-E system

- **Extended training dataset:** Increase the generalization ability of the system by adding more diverse data, including color, shape, and size.
- **Improve text prompt parsing:** Natural language processing techniques can be utilized to accurately parse key information in text prompts to ensure high accuracy of the generated models.
- **Improve detail processing:** Optimize the generation algorithm to better handle details such as color and texture. And after generating the model, the system can automatically perform some fine-tuning to correct obvious errors and defects.
- **More detailed descriptions:** Guide the user to input some more detailed and specific descriptions, including the color, material, shape and other details of the object. This can help the system understand and generate the 3D model expected by the user more accurately.

6.4 Monster Mash tool

- Add undo functionality: Based on the existing interface, an undo function has been developed and integrated to allow the user to freely undo multiple steps, thus increasing the flexibility and fault tolerance of the user during the drawing process.
- Optimise the drawing process: Improve the drawing platform to allow the user to draw the outline of the sketch in sections rather than having to draw it in one stroke. If this were to be realised, I believe a point-to-point connected drawing model could be applied, allowing the user to pause and adjust at each key point. Or the system could introduce more drawing tools such as anchor points, Bezier curve tools, etc. to help the user control the drawing of the outline more precisely.
- Detail enhancement algorithms: Similar to Point-E system solutions, new algorithms can be developed to analyse and enhance the details extracted from sketches, for example using machine learning techniques to predict and refine specific parts of the model.
- Extended animation capabilities: Introducing features such as inverse kinematics (IK) processing and more sophisticated joint control systems to make model animation more natural and professional. Users are also provided with a range of preset animation templates or are allowed to customise animation templates so that they can quickly apply common animations or the animation effects they want to achieve.

In conclusion, by taking these measures, the challenges facing current technologies can be effectively addressed and their development and application in the future can be promoted.

7 Discussion

In this chapter, I will detail the appropriate virtualization strategy for each population based on team size. This categorization allows us to better understand how to choose the most appropriate technology for a specific situation, thus ensuring that the financial investment is proportional to the needs of the project.

7.1 Small-sized development teams

For small teams with smaller budgets, such as students, the biggest challenge to their virtualization is financial constraints. Therefore, the usually best-fitting approach for this group is to use a cost-effective virtualization method.

- **3D Scanning:** Use a smartphone or an inexpensive 3D scanning device to scan. Although the quality of the scan may not be as good as professional equipment, it is sufficient for learning or non-commercialized projects.
- **AI tools:** Use open source or lower cost AI tools for virtualization, for example, you can use Blender to convert photos into 3D models (Boylls, 2023), it does not require much overhead or even every person just need to download the software on your computer.
- **Other resources:** Use free or low-cost software on the Internet, such as TurboSquid, 3DExport, etc., to get some ready-made models to learn and use (Viverse Team, 2023).

7.2 Medium-sized development teams

Medium-sized development teams have some budget support compared to small teams, then they can choose more advanced tools to help them better virtualize their assets:

- **Blueprint conversion:** Blueprints can be converted to 3D models using specialized software such as Revit and AutoCAD which are suitable for projects that require a high replication of real-life scenarios (Autodesk, 2023). For example, for projects involving

historical buildings, a combination of blueprint conversion, laser scanning and photogrammetry can be used to ensure that every detail is accurately reproduced.

- 3D scanning: Choose a mid-priced scanner, such as Crealty Scan Ferret and Revopoint POP 3, with budget in mind (All3DP, 2024), so that you can get high quality models without spending too much money.
- More advanced AI tools: In order to generate higher quality models, use AI tools for commercial design, such as Unity and Unreal Engine (Sibony, 2023).

7.3 Large scale development teams

This type of development team has a large budget, so the results they are looking for should also be the highest quality 3D models. Therefore, for this kind of team, money is a less important limiting factor, but it is not ignored. The following are the most suitable solutions for the high-end:

- Advanced 3D scanning: Use the most advanced 3D scanners on the market, such as the Artec 3D scanner (Artec 3D, no date), which is used by many large companies. It can scan very small items up to entire houses, improving the scanning detail and accuracy.
- Autonomous mobile robotic scanning: Robots equipped with multiple laser scanners can scan with high precision and in all directions in a complex environment.
- Advanced graphics processing software: Advanced graphics processing software and computer hardware are used to process the graphics to ensure that every detail in the 3D model is perfect.
- Advanced AI modeling tools: Use the highest-end AI modeling tools on the market, such as NVIDIA's Omniverse platform, which can be integrated with a wide range of design tools. For example, Sir Wade Neistadt (2021) combines the Omniverse platform with NVIDIA RTX running on NVIDIA Studio drivers A6000, then use RTX rendering to create a natural and coordinated work with realistic visual effects.

In short, development teams of different sizes can choose the most suitable virtualization technology for themselves based on their budgets as well as their needs, which not only optimizes the use of resources, but also maximizes the benefits.

8 Conclusion

In this thesis research, I delve into three techniques for real-world asset virtualization, blueprint conversion, 3D scanning techniques and AI modelling tools. Through a comprehensive analysis of multiple case studies, this research not only tests the real-world effectiveness of some of the technologies in asset virtualization, but also shows the specific challenges they will encounter in practice.

Specifically, blueprint conversion technology has shown good results in managing healthcare facilities, where the virtualization of complex facilities can be achieved through the use of BIM technology, which ensures consistency of information and brings a great deal of convenience to facility managers. However, this technology is highly dependent on blueprints, and the higher the quality and detail of the blueprints, the more accurate the final model will be.

In terms of 3D scanning technology, the use of laser scanning and photogrammetry has successfully created highly accurate digital twins of paleontological exhibits. This technology is particularly suitable for heritage conservation, but the high cost and complexity of the equipment and the need for specialized knowledge base and skills limit its wider application.

In terms of AI modelling tools, firstly the Point-E system demonstrates the conversion from text prompts to 3D point cloud models, offering the possibility of rapid prototyping and creation of virtual content. However, this approach still requires further optimisation in terms of detailing and model accuracy. To address this issue, we can consider introducing a deep learning-based refinement network, such as GAN (generative Adversarial network), to improve the detail and accuracy of the models (Brownlee, 2019). This network can learn lots of 3D model data and automatically generate more precise and realistic point cloud models. Next is the application of the Monster Mash tool, which provides a user-friendly way to quickly convert simple 2D sketches into animated 3D models, enabling non-professional users to quickly convert from sketches to detailed 3D animations, greatly lowering the threshold for 3D modelling. However, it still has limitations in handling complex details and generating high-precision models. To meet the needs of the professional field, we can

combine multi-scale detail boosting techniques which can add model details in the different levels, so as to improve overall quality and visual effects.

In conclusion, although existing technologies have achieved some success in virtualization of physical assets. In addition to the examples mentioned above, the Louvre Museum in France uses 3D scanning technology to copy and preserve 3D models of antiques and artworks in the museum (Wenman, 2015), so that experts can research them and visitors can admire them. When producing the film Avatar, the production team used AI modeling tools to generate the environment of the characters and character animations (AI, 2022), which produced shocking visual effects. And Google's DeepMind developed an algorithm that can help data centers save energy (Moore, 2023), by real-time analyzing data and predicting when electricity is most needed, thereby reducing energy waste and improving running efficiency. Nevertheless, there remain many challenges. Future work needs to improve the popularity and ease of use of the technology, as well as the accuracy and efficiency of data processing.

Through this study, I expect to provide practical technical references for teams in related fields, and provide a theoretical basis for future technology development and application, bringing innovation and value to related industries.

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