Virtual Reality as an Accessible and Engaging Interface to Digital Heritage

A Critical Analysis of VR Literature in the Context of Digital Heritage

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0.1 - Abstract

This review surveys the literature relevant to open source VR development. It encompasses both software and hardware requirements and observes the lack of easy to follow guides for creating open source VR applications.
The review also encompasses a brief history of VR hardware, relevant literature for VR usage in Education and Digital Heritage, and closes with a review of VR immersion.

0.2 - Table of Contents

0.3 - List of Abbreviations and Terms

API - Application Programming Interface
AR - Augmented Reality
CAVE - Cave Automatic Virtual Environment
EULA - End User License Agreement
FOSS - Free Open Source Software
FSF - Free Software Foundation
HMD - Head Mounted Display
Linux - A distribution of a GNU/Linux operating system
ODE - Open Dynamics Engine
OSS - Open Source Software
RPG - Role Playing Game
SDK - Software Development Kit
TOS - Terms of Service
VR - Virtual Reality
XR - Mixed Reality

1 - Introduction

This review surveys the academic literature relevant to Virtual Reality (VR) and educational and scholarly digital heritage applications, and it summarises VR technologies and open source development tools.

VR has been an active area of research for over 20 years and many applications have been explored and piloted. VR games engines have been used for a spectrum of 'serious games' and 'gamification' has been widely used to incentivise user engagement.

In applications such as digital heritage, VR has many potential benefits. It supports virtual tourism for sites that are inaccessible or at risk of damage, and it has the potential to enable access to the majority of museum holdings (typically 95-99%) that are not generally on display. Virtual access to artefacts can also support interactivity so that viewers can have all around artefact views and see views of the artefacts in context and virtually reconstructed; all of which can enrich scholarly, educational and citizen experiences.

However, there are challenges around the development and maintenance of VR environments and the creation of engaging and immersive experiences for a range of target users. These challenges include ensuring that the created application is accessible to all users, which includes issues such as color blindness support.

Another challenge is that often projects are not maintained. This can lead someone who is interested in running an application to seek out a program for their own interest, only to find a program that was abandoned years ago, and no longer works with the current version of any other required software.

In addition to these challenges, software is often locked behind restrictive licenses[1]. This is a genuine issue with developing for the general public, as people may not have the necessary funding, or even the will to pay for some software. As such, it is my firm belief that any software that contributes to knowledge should be free open source software, as to be available to as many people as possible without restrictions on what the software can be used for, or if modifications can be made.

A final challenge with VR applications is the cost of resources. At time of writing, a modest immersive VR system will require a powerful PC[2], and a headset, such as the Valve Index, costing almost £2,000 at time of writing. Lower-cost solutions are available, but these provide lower-quality, less-immersive experiences.

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[1] Such as Unreal Engine's EULA for Publishing, which prevents you from shipping any Unreal Engine code under a "Copyleft license", such as the GPL

[2] A PC capable of providing a high-fidelity VR experience can be found at https://uk.pcpartpicker.com/list/bP4PDc (HMD not included)

1.1 - Motivation for work

The research is motivated by three main factors:

1) A lack of accessible Open Source VR development resources
2) Difficulty in maintaining a product beyond limited project lifetimes
3) The narrowness of current VR target audiences

Despite significant interest in the application of VR technology in a variety of fields, there is a lack of simple, easy to follow guides on creating VR applications. Once a product is conceived and prototyped, often as a part of a short-term research project or exhibition, then the product is no longer being actively developed, with only critical maintenance being performed, such as software vulnerability patches. In addition to this, the product is created for one particular purpose, and hence one target audience. The product may be able to be hacked apart so that it can be applied to other fields of study, but this isn't always the best option.

Therefore, this project aims to create an open source VR application, as well as a framework upon which applications can be developed for other fields. This project focuses on the area of digital heritage, particularly on creating an immersive educational experience within a digital heritage context, for use at home or in a museum by anyone.

1.2 - Open Source Software (OSS)

Open source software is software that has its source code completely available for anyone to freely browse. There are many places where the source code can be stored, such as GitHub. Usually, open source software is available for no cost, and users are able to download and run the software with few restrictions. However, this does not mean that the software is not controlled in other ways, via licensing restrictions.

1.3 - Free Open Source Software (FOSS)

OSS and FOSS are often confused, but they are two different things. Many people assume that the "free" means "no cost", however, this is incorrect.

Free software (sometimes called libre software, from the French or Spanish translation of "Free") is called free software because it protects user's rights when interacting with the software. This often confuses those who simply know it as "free software", as they assume that "free" means no cost. This also gave rise to the phrase "free as in freedom". The four 'fundamental freedoms' of software listed below are defined by the free software foundation (FSF) (Stallman, 1986)

- The freedom to run the program as you wish, for any purpose (freedom 0).
- The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1).
- The freedom to redistribute copies so you can help others (freedom 2).
- The freedom to distribute copies of your modified versions to others (freedom 3).

FOSS freedoms are explained on the GNU project website (FSF, 2019). The FSF is a nonprofit organisation dedicated to a worldwide mission to promote computer use freedom, and encourage the use of FOSS. They developed the GNU Public License (GPL) and the Lesser GNU Public License (LGPL) (FSF, 2007). The two licenses function similarly, and allow sharing source code for any purpose, provided that a copy of the license is included with the code, any changes must be documented, source code is available when the licensed material is documented, and any modifications must be released under the same, or a similar license.

1.4 - Academic Context

This section surveys the literature describing methods of creating, accessible, open source VR applications. Ideally, a paper describing such a method would also provide sample code to help others create their own applications.

One such project is VR Juggler. This project was created as an open source platform for VR Applications (Cruz-Neira, 2002). The accompanying paper, however, provides no links to functional code. In addition to this, the VR Juggler system was built for a CAVE (Cave Automatic Virtual Environment) system, which doesn't seem to be very immersive.

Tecchia et al. (2010) explained a Flexible Framework for Wide-Spectrum VR development, known as XVR. The XVR framework is currently being used by XVR Simulation, in order to provide training services in VR. The source code of the XVR framework is not available, and applications that use the framework must be written in a proprietary language, S3D.

Egger et al. (2017) detailed the integration of OpenVR (using a HTC Vive) into a system called MeVisLab. MeVisLab is a framework for image processing research and development, with a special focus on medical imaging. Unfortunately, while the community can develop addons for MeVisLab, the framework itself is closed source.

A method was described by Edler et al. (2018) for creating a fully open source VR application to construct interactive cartographic environments. However, in this paper, the methodology included using Unreal Engine. Unreal Engine is not open source, as the source code is not freely available to the public, meaning that the entire project cannot be considered as "open source" as the Unreal Engine end-user license agreement (EULA) forbids the distribution of the Unreal Engine source code.

As stated by Collberg, Proebstign, and Warren (2015) software reproducibility is the cornerstone of the scientific process. In their paper they made an attempt via email, links within the paper, or by a web search of systems described within 402 papers to retrieve and implement code to reproduce published results. 176 of those attempts resulted in no access.

2 - VR Development Tools

This section introduces and reviews a number of essential components of VR development. This includes required hardware components, along with a brief history of each, and software components, with some options for those that can be used.

VR is a simulation where the player interacts with a 3D environment, often using specialised equipment such as a head mounted display (HMD) and controllers. VR is an increasingly popular medium, especially for entertainment and education. VR typically incorporates auditory and visual feedback, as well as haptic feedback in some cases, with the aim of delivering immersive experiences.

Augmented reality, often referred to as AR, is an interactive experience of a real-world environment, where objects are projected into the environment, and can be manipulated through whatever device is projecting them. An example of AR technology is to show 3D representations of objects, such as artefacts, in a real-world environment. This is achieved using a smartphone to project the models onto a flat surface, where the user can place the models by simply touching the screen (Woolley et al., 2020).

XR, commonly known as cross reality, is a broad term that encompasses all of VR and AR, as well as mixed reality and cinematic reality. XR technologies have applications in a breathtaking number of fields, such as agriculture, medicine, and digital heritage.

2.1 - HMDs

The manufacture of PC VR systems is dominated by three major companies: Oculus, HTC, and Valve. Other systems, such as the Playstation series of consoles have their own proprietary systems for VR, which will not be covered in this paper. In addition to this, there are other types of HMDs that simply allow the user to slot in a smartphone for low-budget VR. These systems include Google Cardboard and Samsung Gear VR.

2.1.1 - Oculus Rift / Go / Quest

The Oculus Rift was first announced in 2012, and after a successful crowdfunding campaign, was bought by Facebook in 2014. They then went on to release the Rift in March 2016. Recently, the company has announced other HMDs, including the Quest and Quest 2.

The rift line of products are like more traditional VR headsets, the HMD is just a screen, and connects to a computer, which performs all the intensive graphical rendering. The Quest, on the other hand is a standalone headset, where all of the rendering is performed by the HMD.

This means that the headset is easy to set up, as there is no tether required, however graphical performance is limited. In addition to this ease of set up, both HMD series feature inside-out tracking, where the controllers and HMD contain inertial sensors, which update the position of the HMD and controllers in the virtual environment.

Oculus, when they were bought by Facebook said that a user would never require a Facebook account to use their HMDs, unfortunately this promise was revoked for the Quest 2. This makes me distrust Oculus HMDs, as they could now be being used as data gathering tools for Facebook.

2.1.2 - HTC Vive

On 23 February 2015, Valve announced SteamVR, and a demonstration of a "SteamVR hardware system" at GDC that year. The HTC Vive was announced in March 2015, and Valve in collaboration with HTC created the Vive, featuring Room-Scale tracking. Development kits were sent out in August and September 2015, and the product was commercially released in April 2016. The HTC Vive was recently discontinued but the Vive family of products continue to be developed.

2.1.3 - Valve Index

The Valve index was announced on April 30, 2019, and released on June 28. The headset, fully manufactured by Valve, featured an improved controller design, a larger room-scale tracking system, and higher refresh rates than the Vive. Any purchases of the Index also included a free copy of the game Half Life: Alyx upon the game's release. HL:A was Valve's flagship VR game, running on the source 2 engine, and was released in March on Windows, and in May on Linux.

Figure 1
Store page image of the Valve Index Head Mounted Display https://store.steampowered.com/valveindex

2.1.4 - Alternative VR interfaces: CAVEs and screens

Immersive VR usually makes use of head-mounted displays. However, room-based VR is achieved in CAVEs via projected wall displays. Alternatively, VR can be achieved via simple screen interfaces, for example, as used in the intensive care virtual restorative environments by Small et al. (2015)

2.2 - Other Hardware and System Software

Unless the HMD features the ability to render the environment on the HMD, then it's likely that the HMD will need to be tethered to a PC. Usually, The HMD will need three things: power, display, and USB. The power connection provides the necessary power to run the HMD, the display contains the information to show to the user (usually using displayport or a HDMI connection), and the USB provides the headset the ability to communicate with the PC running the application. These three cables are usually connected together, and extended to a significant length, to allow the user to move in the play space.

Tools exist to ensure that the user has the necessary performance to run VR applications. These include the Steam VR Performance Test (Valve, 2016), which will tell the user what they need to upgrade in order to enjoy a stable VR experience.

For a moderate-fidelity VR experience a quad core CPU, with a minimum clock speed of 3 GHz, such as an AMD Ryzen 5 3600, or Intel equivalent would be appropriate, in addition to this, at least 8GB of DDR4 RAM running at 2400 MHz. Finally, a powerful graphics card should be used, such as an Nvidia GTX 1660, or AMD equivalent.

For an operating system: the latest versions of Debian-based Linux distribution are supported by Steam. Other Linux distributions may also work, including an Arch-based distribution, although they might require some tweaks to ensure compatibility.

For Windows: at least Windows 7 with service pack 1 (SP1), but preferably Windows 10. Macintosh laptops are not sufficiently powerful to run VR at time of writing.

2.3 - Application Software

Application software is defined here as software that is required to create the VR application, but not necessarily required to run the VR application once it has been compiled and distributed.

2.3.1 - OpenVR

OpenVR is an API and runtime that allows access to VR hardware from multiple vendors without requiring that applications have specific knowledge of the hardware they are targeting. (Valve, 2015) This allows developers to create VR applications to run on any platform by utilizing the OpenVR SDK.

The SDK was initially developed for use with the HTC Vive, a headset Valve partnered with HTC to manufacture. However, the kit was developed to have multiple vendor support, meaning that the same SDK could also be used to target different platforms, such as an oculus device.

The SDK is provided as source code, and there are instructions to compile it using CMake. It is primarily written in C++, and is fully open source, making it ideal to be used in this project.

2.3.2 - Unity

Unity is a cross platform game engine and development kit, developed by Unity Technologies (Unity, 2021). Unity was first announced at Apple's developer's conference as an OSX exclusive game engine. As of 2018, the engine has been extended to include Windows, Linux, Android, as well as receiving support to create XR applications. Applications are primarily written in C#, but the engine is built on C++.

Unity is, unfortunately, proprietary. While it has always been possible to disassemble the Unity .NET assemblies, and their Terms of Service (TOS) explicitly permits doing so, the TOS does not permit redistribution. In a blog post in 2018, Unity said "*We'd open source all of Unity today if we thought we could get away with it and still be in business tomorrow*".

"...the main engine will remain proprietary for the foreseeable future, and the C# reference source code is released under a license which only permits you to read the code, not modify it." (Pranckevičius, 2018).

2.3.3 - Unreal Engine

The Unreal Engine is a game engine developed by Epic Games, and was first showcased in the game “Unreal” in 1988. Since then, there have been four major releases, with the 5th expected to be released late 2021.

Unreal Engine, often referred to as simply “Unreal”, is primarily written in C++. The source code for Unreal is available, but it is not open source. To access the source code, you will need a Epic Games account, and to be part of the Epic Games Organization on GitHub. This does mean that Unreal is not open source, despite the source code’s easy accessibility.

2.3.4 - openFrameworks, ofxAddons, and ODE

openFrameworks, ofxAddons, and Open Dynamics Engine, is a group of software projects that culminate in a game engine that can be used for a variety of purposes.

openFrameworks (OF) describes itself as an open source C++ toolkit for creative coding. The toolkit is currently in ongoing development, with the latest major release being version 0.11 at time of writing. OF is available for Windows via Visual Studio or MSYS2, Linux 64 and ARM, as well as other platforms.

ofxAddons, is a separate website full of externally developed plugins for OF, that add additional functionality. Addons are sorted by category, including Computer Vision, Game Engine, Machine Learning, and others. This also includes ofxOpenVR, which is an OF-compatible implementation of OpenVR, again written entirely in C++ and fully Open Source.

Open Dynamics Engine (ODE) is a physics SDK that allows developers to get multithreaded accurate physics in a fully open source library. ODE is primarily used for simulating rigid body dynamics, including joints, collisions, and friction. ODE is used extensively in computer games, as well as for academic purposes for virtual creatures.

When these tools are combined, any developer with enough experience could create a high performance, fully open source application.

3 - VR in Education

Freina and Ott (2015) wrote a literature review on Immersive VR in education in 2015. This literature review goes into a significant amount of detail about the uses of VR technology in education, both at younger age education and for adult training purposes.

Vlasov and Borgest (2020) state that "*it is not always possible to quickly transform a rapidly growing body of knowledge about our environment into an interactive form*". A feature such as this can be implemented into the current system by performing a web request to download additional models, in a content manager. Models would be hosted on an external server, and the application could download models either automatically, or at the user's request.

The InNervateVR anatomy VR education system development is explained by Chang-Gonzalez, and Ackley (2019). However, there are little to no development details, and no links to any source code at all.

In an evaluation of VR gamification in higher education (Tiefenbacher, 2020) it is shown that a system of highscores and achievements is less effective at motivating students than a system that applies a time limit on a task or level. Students stated that they felt the time limit to be "disturbing", but this didn't negatively affect the evaluation of the game and their own motivation.

3.1 - Serious Games[3]

Figure 2
Venn Diagram of Serious Games

A 2007 paper by Susi et al. defines serious games as games that are created for other purposes than mere entertainment. These serious games have a variety of applicable fields, such as military, education, and healthcare.

These games appear to come close to simulation games, which can offer a realistic situation that players can experience, to name a few games: Arma 3 (2013) is a somewhat realistic military simulation game, PC Building Simulator (2018) teaches you how to build a PC using a wide variety of components, and Surgeon Simulator (2013) allows you to perform medical procedures, with a VR mode now available (2016).

America's Army (2002) is a game developed by the U.S Army in order to educate and recruit potential soldiers. The first version was released on July 4th 2002, using the Unreal Engine, and has since had my updates and new versions, which have sparked over 13 million total players at time of writing.

[3] Figure 2 Source:
http://flowleadership.org/wp-content/uploads/2016/03/serious_game_classification.png

The Wii Sports series of games (Nintendo, 2006), are a set of sports simulation games released alongside the Wii and subsequent consoles. The original Wii Sports came bundled with the Wii as a free game, that Nintendo wanted everyone to play to help them get up and move, keeping with the Wii's control scheme of having the player stand up and point the controller at the monitor or TV that the Wii was connected to.

These games allowed players to try a variety of different sports from the comfort of their own homes, such as golf, tennis or baseball. The sequel, Wii sports resort, expanded on this, by including even more sports, such as table tennis, swordplay and Archery. Most of the sports are multiplayer, allowing multiple players to take part and compete against each other.

Anderson, et al. (2013) reviewed the use of virtual reality HMDs in education and training, including their use in serious games. They found that HMDs are useful for improving many skills, but show no advantage when compared to less immersive technologies.

4 - VR and Digital Heritage

Digital heritage is the use of technology to preserve culture or natural heritage. The main idea of digital heritage is the transformation of physical objects into virtual copies, which will allow the objects to be preserved in a digital form for future generations, when the physical copies are either unavailable to the public, or they simply become irreversibly damaged.

However, there is the ARCO (Augmented Representation of Cultural Objects) system (White et al., 2004).This system was designed as an architecture for digitization, management and presentation of virtual exhibitions. This involves three steps, firstly content production. The content for the exhibit is acquired, then modelled, and finally refined into a usable 3D model. Secondly, the content is managed. The content is stored in a database and is used in conjunction with the design of the virtual exhibits. Finally, the content is visualised. The content is brought to life in Web + VR presentations, and in Web + AR presentations.

Similarly, in the paper by Collins et al. (2019), two methods of acquiring 3D models from real world artifacts are described. The first method uses a DSLR camera attached to a computer, and the second using a smartphone. In either method the artefact is placed on a rotating pedestal, which is driven by a stepper motor. On the pedestal is a pseudo-random calibration pattern, which is used to calibrate the reconstructed artefact. Once the process is started, a picture is taken, and the pedestal rotates. This repeats a total of 36 times at 10^{o} increments. Once all pictures are taken, the artefact is rotated to capture all sides. Where the two methods differ, is that the method involving the smartphone utilises a custom written Android app, which controls the phone's camera through the camera API, and the rotating pedestal via bluetooth. The other method requires using a computer to control the DSLR, in the prototype in the paper, a Canon DSLR camera was controlled via USB using the Canon SDK. The result is a 3D model of the artefact. However, due to the limitations of the photogrammetric process, unfeatured and reflective surfaces aren't handled as well as others.

Song et al. (2004) writes about a project for "edutainment" purposes. This mix of education and entertainment attempts to enrich learning through an engaging and fun-filled experience that could help engage younger audiences via the application, and provide a more meaningful learning experience.

Another opportunity for creating realistic virtual experiences would be to use the new Nanite feature, which is a part of Unreal Engine 5 (Epic Games, 2020). This feature allows the use of very high resolution environments, which appear realistic in VR. However, Unreal Engine as previously stated, is not open source, and therefore Nanite cannot be used for this project, unless the source code is made available under a different license.

5 - Immersion

Immersion can be defined as a “deep mental involvement in something”. In the context of games in general, this means becoming immersed in the setting of the game, such as the world, story, and characters of a role-playing game (RPG).

Playing games in VR enhances this experience, as players feel as though they actually are the characters that they are playing, since they see the world through their character’s eyes. Clearly, good writing and storytelling have an impact on this, allowing players to relate to the character they are playing in the game. A good example of this is shown in Half Life: Alyx (Valve, 2020) and is discussed in more detail in a video by UpIsNotJump (2020).

In a paper by Brooks (2003), it is shown that if a VR application uses a narrative, then the user, or player, is more immersed in the application, due to becoming immersed in the story worlds, actions, and plot of the narrative.
Brown and Cairns (2004) wrote about a definition for game immersion by interviewing gamers after they had played their favorite game for 30 minutes. They used grounded theory to develop an expansive definition of immersion into the levels of **engagement**, **engrossment** and **total immersion**, as well as immersion.

- In **engagement**: The gamer must first be drawn to the game. If the game is a certain style, or a certain theme, then the gamer won’t even begin to engage. Once this hurdle is passed, the game must also give the gamer something to engage with. Although this is an investment initially by the gamer, the game must provide something that’s worthwhile being invested in.

- In **engrossment**: The gamer is now less aware of their surroundings, and less self-aware than previously. They are involved with the game and only the game, usually not paying attention to anything else. One subject described it as a *“A Zen-like state where your hands just seem to know what to do, and your mind just carries on with the story.”*

- Finally, in **total immersion**: This concept is related to both presence, and empathy. Gamers described presence as if they had been *“...cut off from the world you actually inhabit”*. However, empathy is also important.

In addition, Brown and Cairns (2004) showed that in first-person games or role playing games, gamers feel like they and the character in the game are one. In first person games, you see the game from the eyes of the character, so it is easy to empathize with the characters and hence become immersed. In role playing games, the gamer is taking on the role of a character within the game, and as a result will naturally slip into character, like an actor performing a play, except the play has no script and the gamer can do as they please in the world.

Liszio, Emmerich, and Masuch, (2017) discussed the isolation of players in VR games. Results indicated that social entities within the game decrease the perception of loneliness, and their influence over the experience with players is determined by how interactive they are. However, if the player tries to interact with the entities in a way that was not anticipated, and hence is unavailable, then the immersion is broken, leading to a negative experience.

Slavova and Mu (2018), performed a study, which involved two groups of participants learning about Stonehenge, the first group were given a university-style lecture, with a PowerPoint presentation, and the second group learned the same content, but adapted for use with a GearVR headset. Participants were then given a time-controlled assessment testing their knowledge. This produced the following findings: *"The novelty factor and full immersion in a virtual environment can undoubtedly improve students' attention. However, it is still unclear how the use of VR would impact the learning experience and outcomes with respect to knowledge acquisition"* This seems to suggest that VR is an immersive medium, but further research is needed to measure the impact, if any, on the student's ability to learn.

Johnson-Glenberg (2018) wrote about the positive effect on learning that VR headsets with hand controls have. This shows that a more immersive experience may give increased educational value, which would be a vital part of the application.

An important consideration to allow the player to immerse themselves in the environment is that the environment must seem somewhat real, if this is an expected part of the game. Some games specifically show the player that this won't be happening, but any game that shows the player that a high level of immersion is possible, will build up an expectation of high quality graphics in the player's mind. This can be used with the Nanite system which is a part of Unreal Engine 5. (Epic Games, 2020).

This expectation of high quality graphics can be met with scanning real-world places, and digitally re-creating them in 3D space. This was demonstrated in "La collection Grands sites archéologiques", an extensive collection of French archeological sites (Ministère de la Culture, 2020)

Hartmann et al. (2015) created a scale for measuring immersion. The Spatial Presence Experience Scale (SPES) can be used to measure how immersed someone is in something by questioning them on their self-location and possible actions as a part of an eight item self-report measure. The self-location prompts contain such phrases as *"I felt like I was actually in the environment of the presentation*" and *"I experienced the environment in the presentation as though I had stepped into a different place"*, whereas the possible actions contains phrases such as *"The objects in the presentation gave me the feeling that I could do things with them"* and "*It seemed to me that I could have some effect on things in the presentation, as I do in real life*". This allows participants to grade themselves on how immersed they were in the activity.

6 - Further Research

6.1 - Discussion

This review has discussed the lack of open source guides for creating VR applications, and the importance of ensuring that code for this project is available to anyone that wants it, so that it can be used or modified in any way and for any purpose, and under a license that allows such freedoms.

In addition to this, there was a survey of VR relevant literature, including digital heritage, and open source VR development. Furthermore, information relating to VR in education and immersion was presented and reviewed, with relation to open source development.

6.2 - Research and Development Objectives

1 - Educational
The application should allow the viewing and manipulation of models in a 3D space to improve immersion and educational experience in a museum context.

2 - Immersive
The application should allow the viewing of historical monuments (e.g., Mesopotamian ziggurats, etc) in an immersive and accessible way. VR is an ideal medium for this, so the application should be VR-based.

3 - Open
The application should be made open source so that anyone, museums or individuals, can download the application and models and run it wherever they are. This means that no proprietary software should be required in order to use the system when it is fully working.

4 - Hackable
The application should be able to be modified to suit different purposes. Because the software will be open source, the only requirement is someone with the necessary skill.

5 - Takeaway
The application should allow users to create and export their own models as .stl files for 3D printing, the process of which should be as automated as possible

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