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Utilization of VR-Technology in 3D-Modeling

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Abstract

As the Virtual Reality technology has taken massive steps, it became a relevant question whether the technology had progressed to the point where it could be used to assist or replace traditionally used software, specifically in the 3D-modeling industry. Specifically, Gravity Sketch was chosen due to its popularity and because the client, the Humber College, especially wanted to have the software to be investigated.

The research primarily focused on comparing current solutions for virtual reality modeling to traditional modeling software to see the how differently they would perform when creating a similar object. Another part of research was the interviews where two professionals of 3D graphics were interviewed and their thoughts and answers were analyzed.

The findings suggest that even though technology has improved over some time, VR is not yet capable of replacing traditional software in the 3D-modeling pipeline, however it could have uses in parts of the process, such as early concepting or rough sketches. The collaborative features of Gravity Sketch especially proved to be well accepted and showed potential among research participants. It is expected that VR software will become more prevalent as it continues to advance and more industries adopt it, but VR is currently held back by issues with cost and ergonomics.

Keywords/tags (subjects)

Gravity Sketch, Blender, VR, Virtual Reality, 3D-Modeling

Miscellaneous (Confidential information)

Figures

1   Introduction

1.1   Research Questions and Motivations

This subject was chosen due to students' interest in 3D modeling and VR. In addition, the usage of VR in modeling is a growing field which may have impact in the industry as a whole and as such is worth researching.

The commissioner also requested the topic of using VR along traditional modeling, specifically the usage of the Gravity Sketch application.

With advancements in both modeling and VR technology the question of VR software relevancy in its current state became a subject of interest which narrowed the research questions to:

1. *What are the current states of Modeling and VR technology?*

2. *Is VR technology advanced enough to replace traditional technology?*

3. *Is VR technology advanced enough to be used alongside traditional technology?*

4. *How would one implement VR into a modern modeling workflow*?

Our initial hypothesis is that VR Modeling technology is not yet at the point of being able to replace traditional software, however in its current state we believe it can be used to supplement parts of the 3D-modeling pipeline, specifically the earlier stages of the modeling pipeline, possibly as early as concepting.

1.2   Research approach and methods

The research questions are answered by gathering information about 3D-technology, virtual reality technology and 3D modeling technology, comparing both the traditional and VR workflows for 3D modeling and interviewing experts related to the research area. Information will be gathered from software / software publishers' own websites when possible, such as manuals or user guides, and using web search engines with keywords such as, but not limited to; "History of VR", "Gravity Sketch", "Blender", "VR Modeling Tools", "Manual", "Review", etc.

Comparing both the traditional and VR modeling is researched by using comparative research. The two workflows are examined, and their similarities and differences are acknowledged (Routio, 2007). Comparison is accomplished by creating the same object with both Blender (traditional

modeling software) and Gravity Sketch (Virtual reality modeling software). After the modeling stage is finished and the workflows are described, different attributes can be compared, such as how long the modeling stage took, how easy and intuitive it was to model and what does the quality of the end product looks like.

The thesis includes semi-structured interviews where one or more professionals of 3D graphics are being interviewed by asking questions mostly about the VR technology and how it could be implemented as a part of 3D modeling pipeline. The interviews are semi-structured interviews which mix both structured and unstructured interviews by asking the same questions from all the interviewees (Dudovskiy, n.d.). The interviewees' answers are then analyzed in the results section of the thesis. The semi-structured interviews produce qualitative data which means that the research is considered qualitative research. With qualitative research you try to understand the different things about the topic of a research, for example the qualities, characteristics and meanings (Koppa, 2010). The theory base and the implementation stages support the understanding phase.

1.3   Introduction to the Commissioner

Humber College is the largest polytechnic in Canada, with over 38,000 full-time students studying in over 220 different programs. They were established in 1967 in Toronto, Ontario.

Humber College wanted to know how VR can be used in different scenarios. The qualitative methodology was encouraged to use with the thesis process.

2   Technical Aspects of 3D

As the thesis revolves around 3D modeling, knowing a few technical aspects of 3D will help the reader to understand the research more comprehensively. The following sections will cover some of the most used workflows there are for 3D modeling.

2.1   Key Workflows

The following section will cover all the key features that a 3D modeling software can include. Some of the programs featured in this thesis have a one or many of the workflows. The main traditional 3D modeling tool of the implementation stage, Blender, has all these features.

2.1.1   Modeling

According to Slick (2020), "3D modeling is the process of creating a 3D representation of any surface or object by manipulating polygons, edges and vertices in simulated 3D space" (What is 3D

Modeling?). The 3D representations can be achieved with many different methods, most commonly with manual modeling where you usually create the model from scratch by adding meshes and editing them. Some of the methods will rely heavily on the computational power of the tools and software, such as algorithmic modeling and 3D scanning.

2.1.2 UV-Mapping

Imagine if you had an orange and you wanted to lay the peel of the orange flat without making any cuts to it. You will understand that it is impossible to accomplish due to the form of the orange. UV mapping is a process where you display a 3D model's surface as a 2D image.

There are different ways to unwrap the object into a UV map. They can generally be divided into two methods: Manual and automatic unwrapping. With manual unwrapping you will have to decide where to put the seams, while automatic unwrapping does the work for you by following certain rules (Blender, n.d.-b). A problem one might face has to do with the seams, as they might break the illusion of a continuous texture, so cutting the seams in less visible place is encouraged.

Unwrapping a model will usually create multiple islands which have margins to each other so the textures will not "bleed" onto each other. Sometimes you might want to overlap the islands, if the texture repeats multiple times and having an own island for the face is unnecessary. This will also ensure that the size of a texture is relative lower what makes the method perfect for mobile games.

2.1.3 Materials and textures

To distinct different parts of an object, you might want to use various materials to emphasize the differences in color, roughness, and geometry. For example, a 3D model of a smartphone might feature plastic and glass materials.

PBR materials have become more available in last years and many software and game engines have started to support them. Basically a PBR (Physics-Based Rendering) material can be used to create to an accurate physical material by using different textures for base color, smoothness and metalness (Visao, 2022). Normal maps or height maps are used to manipulate how the light reflect on the material, which makes it look that it has additional geometry and therefore making it a cheap way to make materials more realistic.

There are software which are used to create PBR textures, most notably Substance Painter which is owned by Adobe. The materials can also be acquired from certain websites and they can be paid or free.

2.1.4 Rigging

When creating a humanoid or an animal to be animated, you might want to create a skeletal rig for the object. In the rigging, 3D character's model is being represented with skeletal structure and interconnected bones (Petty, n.d.-b). A human character could have different bones for all the fingers.

When the bones are rotated or moved, the mesh around them is also being affected by them. Using weight controls with vertex painting is a common way in many software to control the effects to the mesh. For example, sometimes you might want the influence of a bone to be larger than it normally is.

2.1.5 Animation

The most common way to animate 3D models is done by using keyframes and timeline. Keyframes will contain information about object's position, rotation, and scale, while timeline decides where the keyframes will happen and how they will be affected by each other.

The last part mentioned rigging, which is quite helpful method for the animating process. For a human character, you could create keyframes for different rotations and positions of an arm and therefore animate the arm. The arm's animation is possible to achieve with either forward kinematics (FK) or inverse kinematics (IK). With FK, you have to rotate every single bone in the arm to achieve the wanted pose, while with IK, all the rest of the bones are affected by the final bone of the arm (Autodesk, 2016). Both methods are suitable for different types of rigs.

2.1.6 Rendering

At some point after the 3D modeling process, you might want to transform the scene into different format than 3D file. Rendering means creating a 2D image or animation out of the 3D scene. After the rendering process, visual effects can usually be added at the post-processing stage, for example, motion blur.

Different software can offer different render engines to use, such as Octane, Cycles, Arnold, and Redshift, thought most of the commercial render engines use ray tracing in order to create accurate and photorealistic results.

2.2 Manual Modeling

Manual modeling is the most common way to create 3D objects. It means that you do most of the generation of the meshes and the editing of the meshes. Manual modeling can be roughly divided into three different methods; Polygonal modeling, spline modeling and sculpting.

The following parts will explain the differences with the methods.

2.2.1 Polygonal Modeling

Polygonal modeling's basic principle is to build 3D objects using smaller components, such as triangles or polygons. (Spatial Team, 2019). Triangles and polygons are made of vertices, edges and faces.

Polygonal modeling gives a 3D modeler a chance to create more unique designs and the modern computers work great with optimizing polygons. However this method can take a lot of time and it's highly prone to human errors (Spatial Team, 2019).

2.2.2 Spline Modeling

Spline modeling is based on Non-Uniform Rational B-Splines (NURBS) where the geometry is done by using geometric primitives and curves (Autodesk, 2021).

NURBS are flexible and accurate with many different use cases in software, engineering, design and animation teams (Rhinoceros, n.d.). The technology is also great for organic model because the curves surfaces they will provide.

2.2.3 Sculpting

3D sculpting is similar to real life sculpting; You use various tools to pinch, pull, carve or inflate to work with a 3D mesh's geometry. It is mostly focused on deforming lines and adding more details onto the mesh (3D-Ace, 2021).

A widely used application for sculpting is to create a high poly version of a low poly model and then bake the sculpted details onto the low poly version. This is necessary because sculpting can create millions of triangles which affect the performance.

Some 3D modeling software include tools for 3D sculpting and there are also dedicated software for the method, the most known example being ZBrush.

2.3   Algorithmic Modeling

One type of modeling which popularity has been risen lately is algorithmic or parametric modeling. It uses pre-programmed algorithms and values to create 3D models. One of the main benefits of this process is its ability to edit the mesh's geometry by changing the values, so it will save a lot of time and effort (Bichakhchyan, 2022). In addition to creating 3D models quickly, designing can be highly efficient and different styles are accomplished easily, natural, or futuristic shapes etc.

Of all the 3D software there are, Houdini would be the closest to a program which workflows are heavily based on algorithmic modeling.

2.4   3D Scanning

One interesting way to create 3D models is 3D scanning. It is done by collecting data from the real world in order to replicate it digitally using different methods and machines (Sculpteo, n.d.). Two common workflows for 3D scanning are laser scanning and photogrammetry.

Laser 3D scanning is considered as a common way to 3D scan objects. It is implemented by using a laser scanning device to scan an object's shapes to create a digital version of it. One of the best reasons to use this technique is the quality and accuracy of the details while capturing complex objects (Sculpteo, n.d.). Its nature of capturing minute details makes it really useful, for example, in industry related fields. Subscription-based racing simulation game iRacing is known for using laser scanned tracks in the game because the technique provides identical and similar experience of real-life racing tracks with all the bumps and pockmarks (iRacing, n.d.). File sizes of the laser scanned tracks are relatively huge which must be taken into account in terms of intended use.

Photogrammetry is another popular method of 3D scanning. It generates a 3D model based on photographs taken from different angles. The photographs are typically overlapped, and they can

be captured by using either aerial or close-range methods (Autodesk, n.d.). The image below (Figure 1.) is displaying an example of close-range photogrammetry of a barn with all the photographs taken.

Figure 1. Example of a close-range photogrammetry workflow (Bitfab, n.d.)

Recently Apple has been releasing phones which have a built-in lidar sensor attached. Lidar (Light detection and ranging) is a method of sensor, which uses a laser to determine ranges, which are measured using the reflected light (National Ocean Service, n.d.). Different apps have been developed for iOS that use the technology to scan the wanted objects real-time and efficiently.

2.5 Topology

Having a clean topology is one the key factors to ensure that the model you have created has capabilities to function well with different usages. Topology means how an object's vertices, edges and faces are distributed and structured (TurboSquid, n.d.). The image below (Figure 2.) shows two examples of how topology can be achieved.
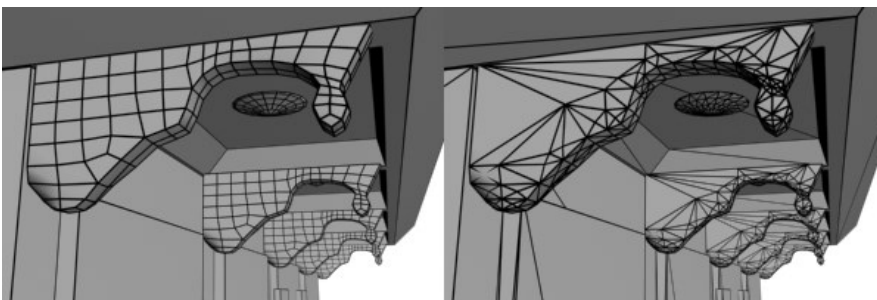

Figure 2. Example of good and bad topology (TurboSquid, n.d.)

The left part of the image shows an example of clean topology while the right one is generally considered as bad topology. The most notable difference is that the left is made of quads and the right is made of triangles (TurboSquid, n.d.). The left example looks cleaner to a viewer. Editing, UV-mapping, rigging, and animating the model are also affected by the structure of topology. For example, good topology allows easier modifications to the model in later stages (CGISCIENCE, 2021). It makes the process less painful.

It is common that the topology of a model needs to be edited. The term for modifying the topology for cleaner and better is called retopology which might be useful if the model is being deformed in future (Blender 2022). While the topology can be fixed manually, there are tools which can accelerate the process far more robustly. For example, Autodesk offers a few retopology modifiers for 3ds Max, such as ProOptimize (reduces overall poly count), subdivide or smooth (Autodesk, 2022). Different addons or tools can also help you with retopology, such as RetopoFlow, which is made to aid with creating a lower poly count version of a high poly mesh (Orange Turbine, n.d.). Low poly versions are necessity for many use cases.

2.6   File Formats

With all the different purposes and software for 3D models, a question might be raised which file format you should use for your model. A 3D file contains properties about the file itself, such as geometry, materials, lights, skeletal rigs, and animations. Different file formats support different features and some of the programs only accept certain formats. The file formats can be divided into neutral and proprietary 3D file formats, the former being able to be used in different software, while the latter is tied into a certain program (Crowder, n.d.). Explaining all the file formats there would make the text too long, so we focus on some of the most popular and versatile ones being used.

The file formats this section will be focused on are FBX, OBJ, STL and DAE. The FBX format is a proprietary format developed by Autodesk with popular usages being game development and animations. Although it is proprietary, many software outside the Autodesk ecosystem can use the file format (FileInfo.com, n.d.-a).

The OBJ is another popular file format, which is widely supported by different software and its text-based format has made it available in different environments. Being a text-based format, it can be opened with a text editor, which makes the format really modifiable (FileInfo.com, n.d.-d).

STL is a format which people usually come across when they are working with 3D printing applications. It is named after stereolithography which is a form of 3D printing where the materials is added layer by layer (FileInfo.com, n.d.-c). STL is also possible to open with a text editor. Many software support DAE which is a 3D interchange file developed by Sony. It's based on the COLLADA, which current owner is Autodesk (FileInfo.com, n.d.-b).

3   History and Current State of Modeling Software

3.1   History of 3D software

The film industry has always been a significant factor in the development of 3D graphics. The early 3D films were released in 1920s and the golden age of 3D technology was the years between 1950 and 1960. After that, it fell into obscurity, but with the development of technology, it has resurfaced in the 2000s (American Paper Optics, 2022).

One of the first usages of 3D computer graphics was accomplished by Ivan Sutherland in 1960 when he created a computer application called Sketchpad as a produce of his thesis at MIT. The software was used to draw directly on the computer monitor to generate single shaped 3D objects. (History Computer Staff, 2022; 3D Horse, 2017). After the 60s, the technology has advanced drastically.

Edwin Catmull has been one of the pioneers of developing 3D graphics. For example. he co-created the world's first 3D rendered movie (HistoryofInformation, n.d.). With Jim Clark, Catmull developed the Catmull-Clark subdivision, which is a method to smooth a 3D mesh by diving the polygons into smaller polygons. Nowadays it's a standard method for smoothing meshes and the result is much more smoother compared to the simple subdivision (Algosome, n.d.).

3D printing has also become more popular than ever before. 3D printing creates solid 3D objects from a digital file by using a 3D printer, which lays down layers of material until the finished results is ready (3DPrinting.com, n.d.). The technology has advanced and for a regular person, a 3D printer is more affordable than ever.

3.2 History of VR

3.2.1 Evolution of VR

Virtual reality development started in the mid-1900s with one of the first devices that could be described as 'virtual reality' being the Sensorama, a booth-like machine for up to a few people that would stimulate the viewers' senses as they watched short movies developed for it. It was developed by cinematographer Morton Heilig in 1956 and a total of six films were created for it. (Barnard, 2019).

The first modern Head-Mounted Display (hereafter referred to as HMD) was developed in 1968 by Harvard professor Ivan Sutherland, though this 'Sword of Damascus' was a heavy, intimidating contraption suspended from the ceiling due to its weight (Barnard, 2021). Most early HMDs were cumbersome, specialized devices that were built to serve a single purpose, such as training air force pilots (which is still a common use for VR cockpits to this day) or helping war veterans struggling with PTSD. The first VR system designed for consumers came in the form of VR arcade machines, where users would sit in and wear a pair of virtual reality goggles, with the first form of home VR coming with the Nintendo Virtual Boy in 1995.

In 2010 Palmer Luckney created what would be the first form of modern home VR: the Oculus Rift. In 2012 the Oculus Rift started a Kickstarted, raising $2.4 million. The company was then bought by Facebook in 2014, which was the defining moment for home VR. The technology started to pick up momentum rapidly after this and by around 2016-2017 hundreds of companies were developing VR products or devices (Poetker, 2019). The first truly modern, commercial VR set came in 2016 in the form of the HTC Vive.

VR Technology was also becoming more available and diverse around this time with more VR experiences being developed and becoming available around the world and as VR sets become more available and affordable. Nowadays VR is more accessible than ever, some sets not even requiring a PC.

3.2.2 Applications of VR

The applications of VR have become more and more diverse as the technology is adapted by more and more industries. Traditionally VR has been used to train employees and workers in certain

fields such as aviation, with VR cockpits letting pilots practice flying and maneuvers in a safe environment, though the idea was adapted by other educational fields such as driving schools or even schools, allowing students from all over the worlds study in an immersive environment, the technology also enabling students of all backgrounds to receive education, which may have not been possible before (Thompson, 2022).

The technology has recently been seeing more use in the medical industry as well, with it providing a way for doctors to become more familiar with new tools and devices, as well as practicing procedures such as surgeries, or even just doctor-patient interactions. VR is also being used to treat mental health issues, or even as tool for behavioral therapy (Thompson, 2022).

VR has also seen more use in entertainment, with many websites, such as Youtube or Netflix, offering 360* movies or virtual reality experiences such as interactive movies in which the viewer can directly influence the story's progress, or gain extra information about certain aspects of the experience. VR-gaming is also becoming more prevalent with more and more studios developing games specifically for VR, some old games being ported to VR and more and more games at least supporting viewing the game through an HMD.

VR also allows new forms of creativity that might not normally be possible (in general, or to certain groups of people), and more forms of art are becoming available on the technology, such as music which has been a recent trend. VR modeling is also becoming more common and developed, as the technology allows users to manipulate and view their creations from many more angles, allowing better control over the creations – though the technology is still vastly inferior in many aspects to traditional media. In some industries, such as the automotive industry, VR technology has been used for years to assist in design – allowing large companies to save money by not having to manufacture prototypes (Thompson, 2022).

3.2.3   Future of VR

"The VR field has come a long way in the past 50 years, but is still an emerging field" (Poetker, 2019. The history of virtual reality section). The technology will continue to become more and more accessible through smaller sizes and lower costs.

Devices that allow more senses to be linked to the device are also being developed to create more immersive experiences. Some companies predict that:" by 2030, we will be able to enter digital

environments that appear completely real to all five senses simultaneously" (Marr, 2020. VR in Industry and Work section).

Advancements in the field would also allow mixed reality (MR) solutions to become more viable as well and lead to solutions such as smart glasses that would allow users to always have a virtual assistant with them, or to play games or experience mixed reality experiences seamlessly while walking around, for example. Better VR/MR solutions could also be utilized in industry, where employees could work from a safe space or even home operating machinery remotely.

Remote learning and education are expected to become more prevalent as the technology becomes more readily available. Students with medical issues or without access to traditional education could receive it just the same as any other student. It has also been researched that (at least in some fields) VR education can facilitate better learning with less stress and associated issues (Zhao et al., 2021).

3.3 3D-Modeling Software

The following section will cover some of the most known and used 3D modeling software there are. All of them have at least one thing in common: They can be used to create 3D graphics and models. Although a few of the software have significantly more features than some of them.

Blender will have its own part due to it being the main 3D modeling software used in the implementation section of the thesis. It also has a few more things which support it as a software of choice. First, it is free for everyone to use and does not require payments like most of the other software named in the following parts. That is due to Blender being an open-source software. It also has several features, such as modeling, texturing, and animating workspaces, which make it a perfect tool for a complete production setup for game asset development. Of all the other 3D modeling software, the thesis worker working with the implementation part related to traditional 3D modeling software, has the most experience with Blender, what is a key factor to make the thesis more reliable and validate

3.3.1 Maya

One of the popular software is Maya which is an professional 3D animation and visual effects software for different sorts of applications, such films, TV, and video games (Autodesk, n.d.). Maya is owned and developed by AutoDesk.

"If you want to work in the animation industry, you'll find that more companies appreciate a working knowledge of Maya" (Fuentes, 2021, Final Thoughts). Maya's focus on animation workflows and animation tools is one of the main reasons why it is considered an industry standard, at least for large game development studios and animation studios. However, while the largest studios would use Maya, for an indie studio or an individual person, Maya's subscription model might be harshly expensive.

3.3.2 3ds Max

Another professional 3D software is 3ds Max which can be used to 3D model, animate, and render everything for games and design visualization (Autodesk, n.d.). Like Maya, the software is also owned by AutoDesk.

A question might be raised how 3ds Max is different to Maya and is it better in some specific method. Petty (n.d.-a) states that "when it comes to modeling 3ds Max is unmatched in speed and simplicity" (What is 3ds Max?). That might be one reason why it is widely used in different industries. Like Maya, 3ds Max uses a subscription model too.

3.3.3 Cinema4D

German company Maxon is the owner of Cinema 4D, which can be used for 3D modeling, animating, simulating, and rendering. It is one of the most popular 3D software and its toolsets for motion graphics and visual effects are renowned for accessibility and efficiency (Maxon, n.d.-a). It is subscription based, with either monthly or annual payment.

3.3.4 Houdini

Houdini is a 3D software delivered by SideFX. The software is highly different to the rest of the software mentioned in the thesis as it relies heavily on the procedural or node-based workflows.

Actions are stored in nodes which are wired into networks and their attributes will add to Houdini's procedural nature (SideFX, n.d.). The software is mostly used in film and tv sets, but it is not super rare in game development environments.

Working with procedural workflows can be effortless and very accurate when needed, which made Houdini an industry standard in visual effects fields in film and TV industry.

3.3.5   ZBrush

ZBrush is a popular digital sculpting and painting software provided by Maxon. It is considered as an industry standard in its main areas, and it features a wide set of tools for different professions to use. (Maxon, n.d.-b).

In addition to sculpting, ZBrush has some polygonal modeling features for creating hard surface models. However, its main purpose is sculpting and painting.

3.4   Blender

The following section will be dedicated to Blender software. The software deserved a larger part than the other software mentioned as it is the software that is used during the implementation part of the thesis. The section will cover the history of Blender and some of the key features Blender offers.

3.4.1   History of Blender

The history of the software goes back to the 90s. It was created by Tony Roosendaal, who used to study industrial design in the Netherlands. but dropped out. In 1989 he founded a 3D animation studio NeoGeo, which became a huge success in his home country. The foundations for Blender were laid in January 1994, when Roosendaal created the first source files were named "Blender" (Blender, n.d.-a). A few years after NeoGeo closed and a company called Not a Number (NaN) was founded by Roosendaal and his partner Frank van Beek. They distributed Blender as a freemium software, which had paid advanced features (Blender, n.d.-a). The new business model provided a lot of income, which greatly benefited the owners.

Even though NaN was able to acquire millions dollars of funding, it unfortunately closed in 2002 due to multiple economic problems and the development of Blender stopped. Roosendaal could not buy the rights for the software, so he started the Blender Foundation in May 2002 in order to

make Blender open source. He also held a crowdfunding campaign, which was supported by hundreds of thousands of Blender community members, to acquire Blender back from the investors (Blender, n.d.-a). The meaning of open source is explained in another part. Blender was released later that year and its open-source contract will keep the software and its source code free for anyone to use (Blender, n.d.-a). Being a free open source software is nowadays one of the key elements it is known for.

In recent years, Blender's biggest upgrade was the 2.80 release, which redesigned the user interface and changed some of the controls. For example, mouse left click was now the default for selecting the objects. Introducing new workspaces was also a large thing in the release. (Blender, 2019).

3.4.2 Features of Blender

Blender has tools for almost every step of creating 3D models for films, animations or games. Its default layout features workspaces for modeling, sculpting, UV editing, texture painting, shading, animating, rendering, compositing and scripting. In addition to 3D, 2D animations are also possible to create with the software.

Algorithmic or node-based systems are also common in Blender. The materials can be created with nodes and the recent introduction of geometry nodes has opened doors for many possibilities.

Blender features two prominent render engines; Cycles for ray-trace based renders and Eevee for real-time rendering. Cycles requires more hardware than Eevee, but results in more accurate renders, while Eevee's real time functionality could work well for simple 3D scenes.

3.5 VR-Modeling Software

3.5.1 Blocks By Google

Blocks is a relatively simplistic tool designed for low-poly modeling for users of any skill level. It has a generally limited all-rounder toolset, with specialty features such as precision polygon placement to reduce rendering cost as well as the ability to do simple animation by directly controlling and recording motions for the object or character.

3.5.2   SculptrVR

SculptrVR is part game, part modeling program. Compared to other software, its toolset is quite limited, but in exchange it utilizes voxel-technology to allow extreme detail and zoom levels to your work. SculptrVR also advertises to have procedural generation functions for things such as landscapes (though this is more for the 'play' mode rather than creating things) (Kaye, 2021).

The software allows multiple users to collaborate on projects, but also to then use that model or creation in a 'play' mode, essentially turning the creation into a game.

3.5.3   Masterpiece VR

Masterpiece VR (also known as Masterpiece Studio) is a suite of VR-modeling tools designed for professional use. It has a full suite of tools for modeling, sculpting, texturing, and animation that rivals traditional 3d-modeling software. It is, however, also the most expensive software that we compared.

It advertises an "unique auto-rigger function and auto-skin function which can allow you do to do the entire model in just a single click." (Kaye, 2021. Masterpiece VR Section) It also has collaboration functions that allow multiple users to work on the same project in real time as well as functions to stream your work onto social media.

3.5.4   Tvori

Tvori was designed to be as beginner friendly as possible, to act as an entry point into the VR (and 3d-modeling) world. It has a highly rated, intuitive user interface and is in general very user friendly. The software was designed to be used to design and prototype interfaces and products but has extensive (real-time) animation features as well.

Tvori is also heavily community-oriented, as it has been made easy to share your creations and to import others' creations via a 'Shelf' tool.

3.5.5   Adobe Medium

"Created to be intuitive for every level of user, Medium by Adobe is especially great for character modeling in VR." (Kaye, 2021. Medium Section) It specializes in character design, with a wide set of

tools ranging from sketching to sculpting among others. It also supports layers to help with complex models. It also allows users to collaborate on a single model. As part of the Adobe family of programs the model is easy to use in other programs such as Substance Painter as well but can also be exported to various formats (Adobe, n.d.).

Medium is generally regarded as one of the best VR sculpting software, with an extensive toolkit for sculpting and fine-tuning. Its main drawback is that it only supports Oculus-family VR headsets.

3.5.6   Gravity Sketch

We ended up selecting Gravity Sketch as the main VR tool we will be using for this research. There are three main reasons for this choice: Gravity Sketch is a free software, Gravity Sketch was specifically requested by the client and Gravity Sketch is being actively developed, with new features being added all the time.

Gravity Sketch is a VR Modeling software with an emphasis for collaborative work. It was designed to be a tool for 3D-sketching and design but has a toolset that allows more demanding work as well. It utilizes VRs specialty: not being limited to two dimensions when designing and looking at a creation, and using a three-dimensional cursor to draw instead of a mouse and keyboard (Boyd, 2022)

3.6   Open-Source Software

Open source is a term that occurs a few times in the thesis. Open-source software is software with source code that anyone can inspect, modify, and enhance (Opensource.com, n.d.). There are different license models that specify an open source software's properties more accurately.

4   Example Workflows

The following part will show the modeling workflows with both Blender and Gravity Sketch.

4.1   Reference Images

Reference images are essential when you are 3D modeling something that exists in real life and has accurate dimensions. If you can use only few reference images, picking ones from side and

front views of an object are preferred. Additional images from top and bottom can be used too to bring more accuracy into the modeling process.

For the modeling processes of the thesis, an ice skate was chosen as a target object. It has symbolic value to the research because the thesis workers are from Finland and the client is from Canada. Both countries are known for their love for ice hockey and ice skating in general.

Figure 3. The reference image for both methods

4.2   Modeling in Blender

The modeling process of the ice skate with Blender starts with opening the software. The default startup file will feature a cube mesh, also known as the "default cube". You can start the modeling by editing the cube, but for learning purposes, the cube will be deleted this time by selecting the object with right-click and pressing the key X and confirming the deletion (Figure 4.).
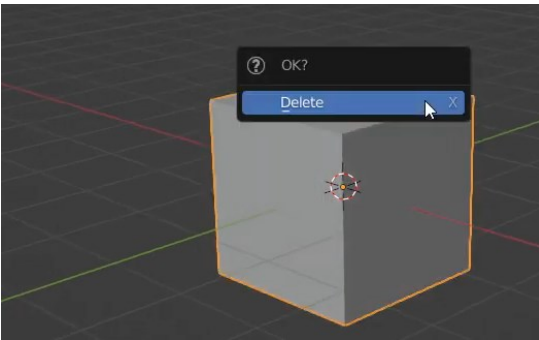
Figure 4. Deleting the default cube

After the deletion, the scene will now feature two objects; Camera and light. Both objects are necessary for the rendering of the scene, so removing them would complicate later stages, especially if you want to see how the materials look. Next step is to import the reference image. It is done by pressing Shift + A, choosing Image and Reference. Then you can search the image from your file explorer. However, there occurs a one problem; The image is rotated towards the view. This can be fixed by pressing Alt + R, which restores the image's rotation (Figure 5.).
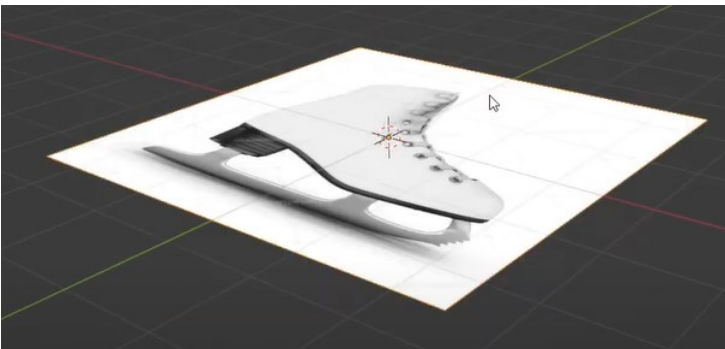

Figure 5. The reference image with restored rotation

By pressing the numpad key 3, you can quickly change to side view and see how the image looks from that angle. The image needs to be rotated 90 degrees both in Z and Y axis. The current size of the image is quite large in terms of the units, so it can be scaled down by selecting the image and pressing the key S. Then, by pressing key G, followed by key Z, the image can be moved along the Z axis in order to position it properly. If you have more than one reference image, the images for top view and back view are preferable, especially if the subject has complex shapes.

After placing the reference image correctly, you can then start the modeling process by adding a mesh. A cube is generally a great starting point as it is made of quads and therefore offers a foundation for good topology. You add a cube by pressing Shift + A, choosing Mesh and Cube.

Changing to different shading mode fluidly in viewport display can be achieved by opening a pie menu with pressing Z (Figure 6.). Wireframe and solid modes are quite handy during the modeling process while Rendered and Material Preview modes are useful for the material creation process and rendering.
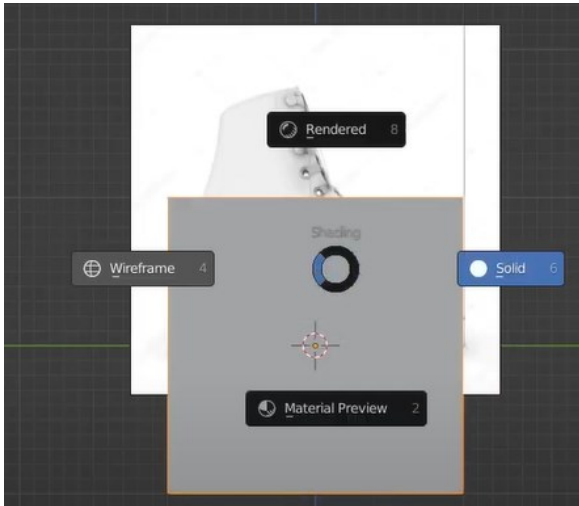

Figure 6. Pie menu for shading viewport display

Instead of the ice skate being a single object, it is better to build it from a few distinct parts. In this case, we have shoe, sole and blade objects. We will use the cube we added before to create the shoe part. Using the key Tab, we can change between object mode and edit mode. With the edit mode, we can edit the mesh however we like. Pressing key 1 allows you to edit vertices, key 2 does the same for edges and key 3 is for faces. In Figure 7, selecting and moving the vertices is done to match the shape and lines of the reference image. This is done via the wireframe mode because selecting the vertices in solid mode only selects the vertices in front and leaves the vertices in back unselected.

Figure 7. Editing the shoe mesh

At some point of the modeling process, you might want to increase the amount of geometry the mesh has. One solution is to create a loop cut, which creates a cut along the mesh and therefore new vertices. Then you can grab and move the vertices into new positions and make the shape of the mesh more accurate to your reference.

Another solution to create new geometry is to use extrusion tools. For example, by selecting one face of the cube, you can press the key E to extrude, which duplicates the selection and moves it along the normal of the face. The new geometry created in Figure 8 has been done by extruding a face and moving it to the right position. Then it was fine-tuned by using both the grab (G) and scale (S) to match the reference image. Selecting a face and using a combination CTRL + right-click will extrude the selection into the position of the mouse cursor, which is a quick way to create new geometry.

When you get more familiar with the program, you will recognize the situations where a certain method of creating new geometry will be suitable.
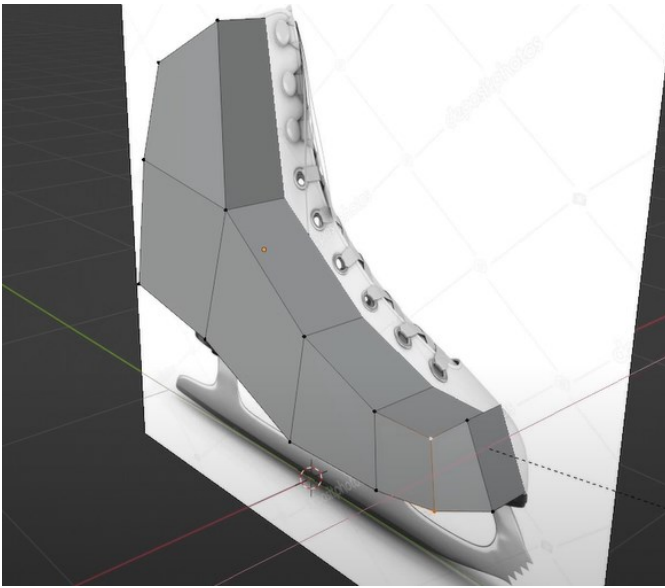
Figure 8. Editing the shoe mesh

Loop cuts were mentioned before as a way to create new geometry. For the ice skate, a loop cut is especially used to add more details to the existing geometry. Figure 9 shows the technique clearly; You move your mouse cursor close to an edge, press the combination CTRL + R to highlight the position where the loop cut will be added and finally confirm the loop cut by left clicking. By default, it is positioned in center of the adjacent edge loops, but by using the mouse, it can be moved to desired position and then confirmed by using left click.

Figure 9. Adding a loop cut

While editing the mesh, you can turn the proportional editing on. This option will display a circle of influence when you, for example scale or grab a vertex (Figure 10.). All the other vertices within the circle will also be affected by the action. Scrolling the mouse wheel will increase or decrease the size of the circle. This mode is incredibly useful when you want the mesh to feel more natural and smoother.
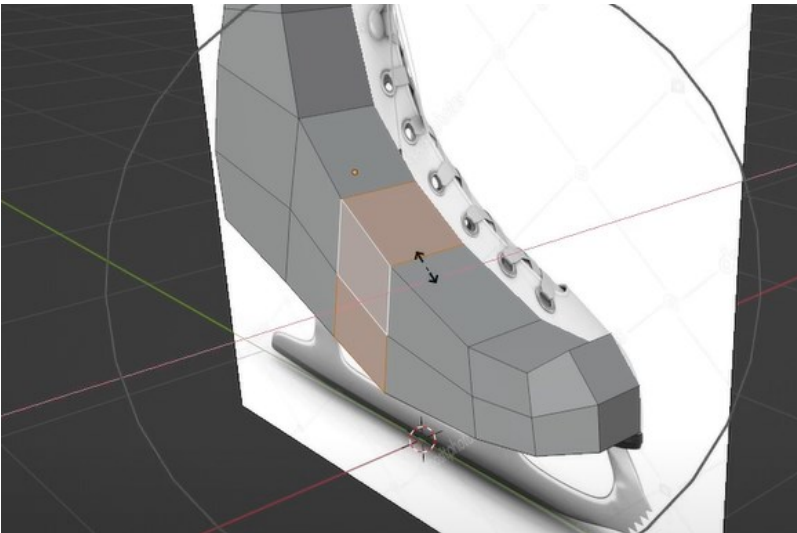
Figure 10. Propotional editing

The whole 3D modeling process can be accelerated by using the mirror modifier, which mirrors the mesh along a certain axis of the object. The mesh needs to be sliced half, so a loop cut needs to be created in the middle of the mesh. Then you select the other half and delete the selected vertices (Figure 11.).

Figure 11. Cutting the mesh into half for the mirror modifier
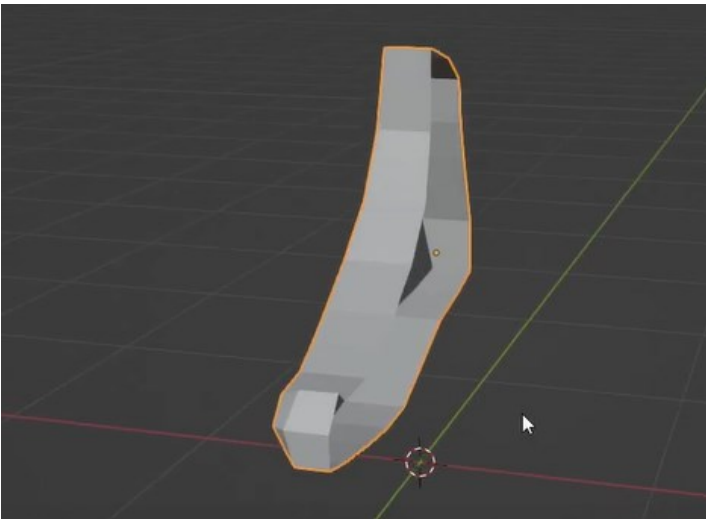
Once there is only a half of the mesh left, you select it, go to the properties pane on the right, click the wrench icon and add the mirror modifier. The settings let you choose which axis you want to use for mirroring etc. Default settings will done fine this time, except Clipping should be turned on, so vertices are prevented from going through the mirror (Figure 12.).
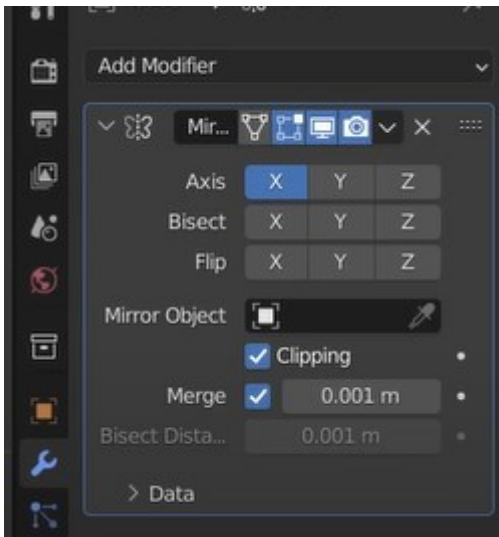
Figure 12. Mirror modifier properties

The mirror modifier makes the modeling process less frustrating as you do not have to make sure the other half of the mesh looks correct. After activating the modifier, you can edit and move the vertices to make the shoe smoother and more realistic (Figure 13.).

Figure 13. General shape of the shoe part

The shoe object is edited more in future, while the sole mesh is created next. There are countless ways to create it, for example, by adding a cube, moving it to correct place and editing the verticies. This time, a different method is used, due to introducing new features. You start by selecting the shoe's bottom faces, which you then duplicate using SHIFT + D. After the duplication, you right click the mouse to set the newly-created faces into same place where they originally were. Pressing the key P will let you separate the faces by selection and it will create a new object from them.

A basic form of a sole can be created by selecting the faces of the new object and extruding them outwards a few units (Figure 14.).
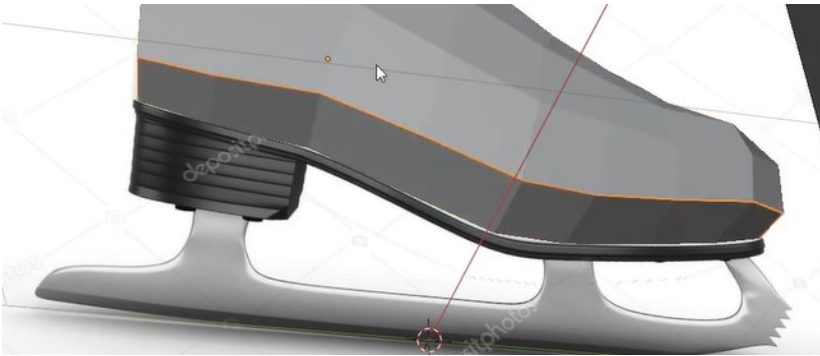
Figure 14. Creating the sole part

The sole part's modeling is continued by extruding a few faces to make it looks like the sole in the reference image (Figure 15.). This part of the whole model will not need to much geometry cause it will not be as visible as the other meshes.

Figure 15. Editing the sole part

After the sole part Is roughly modeled into proper shape, you could add basic materials onto existing objects. The shoe will have a white material and the sole will be colored with dark color (Figure 16). Material's roughness value is set to 1 which means it does not have reflections.

Figure 16. Adding basic materials for different parts

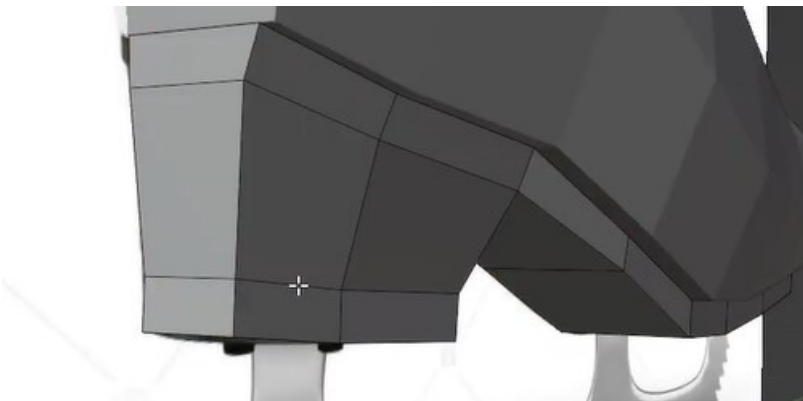Once the basic materials have been added, a mesh for the blade can be added (Figure 17). Its modeling process is also better to start from a cube so adding new geometry and editing existing one happens fluidly. The process is simple; You select faces and extrude them out to match the reference image.

Figure 17. Editing the blade part

Additional loop cuts can be added to mesh to create more rounder bevels for the blade (Figure 18). One trick for beveled edges would be to use the bevel modifier, but its usage can be hard to understand and it may also create triangles, which are not desirable. After the blade has been modeled, a material with metallic value set to 1 can be added onto it. You might want to change the roughness value to match the wanted glossiness.
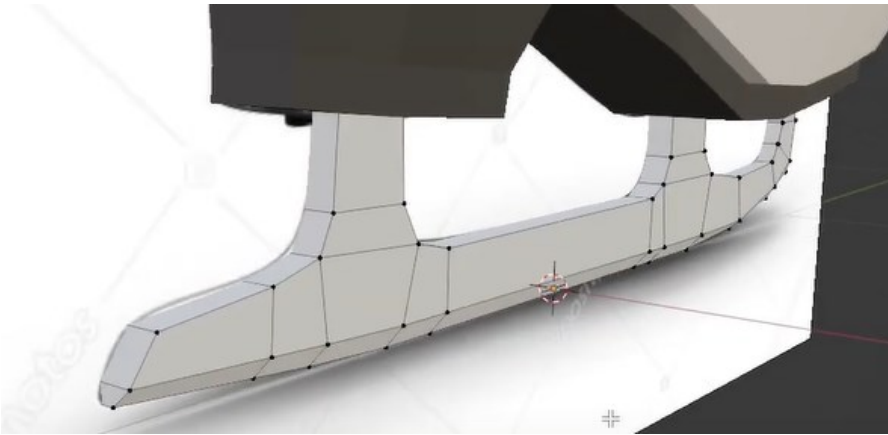
Figure 18. Editing the blade part

Figure 19 represents the full model in the wireframe mode. Its polycount is relative low which means the model is considered to be low poly. The shading mode of a object can be flat or smooth. Deciding which shading to use is a personal preference and can affect the style and vibe of the object drastically. Figure 20 displays the model with smooth shading and materials.
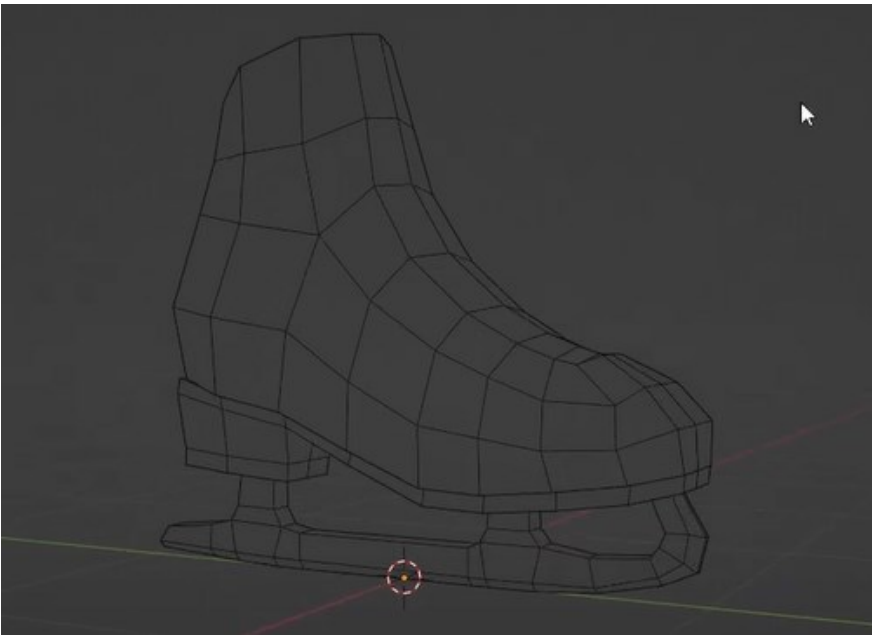

Figure 19. The ice skate in wireframe mode

Figure 20. The ice skate with materials and shading

4.3 Modeling in Gravity Sketch

To start the modeling process in Gravity Sketch you start out by selecting 'New Sketch', which puts the user in a completely blank workspace. Inside the program you have two controllers, our primary and non-primary hand respectively, where the former is primarily used to add to the sketch and manipulate it while the latter is used to manipulate the scene and choose tools. By clicking the menu button on the non-primary controller, you can open a menu where the user can bring in their reference image simply by dragging it out with the other controller via the grab buttons.

To start off, it is recommended to create a rough outline using the stroke tool (which is selected by default when the software is started) and simply using the trigger to draw, using the non-primary controller to hold the grab buttons to move the entire scene, allowing us to add depth to the rough sketch. Once you have a rough sketch you can use another option in the menu to switch over to a new layer and lock the previous one, allowing you to draw/model over the sketch.

Figure 21. Tracing over the reference image.

While the stroke tool is good for sketching and creating rough outlines, it is effectively just a line drawn in a 3D-space, with limited editing capabilities. For cases where simple lines are not good enough one can insert primitive models into the sketch. To accomplish this: you use the tool selector on the non-primary controller and select the primitives-tool, where you can then select what kind of primitive you want, using the trigger to create a simple box, the grabbing it with the other controller to flatten it out.

While holding the cube with the primary controller you can then press the menu button on the other controller to open the object options, where you convert the object into a SubD object, allowing access to more tools to edit the model with. After being converted into a SubD object, you then have the option to switch to either the loop cut or slice tools on the primary controller, both are effective for creating editable points, but loop cut is preferable for symmetry.
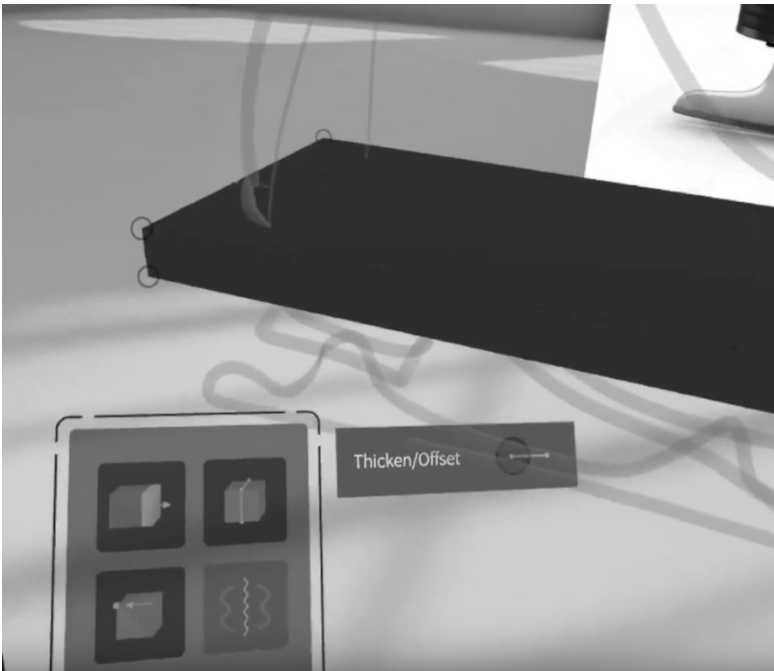
Figure 22. Converting the object to a SubD object.

You can then simply grab these points with the primary controller to manipulate them, not unlike simply dragging points in traditional software. You can then create another box, or other such shape, to create the rest of the bulk parts of the shoe. Manipulating primitives/SubD models like this is the most effective way to create larger parts of the model, but not as effective for creating round and curved parts, in addition, not all primitives can be converted into SubD objects.

Figure 23. Using the loop cut tool.

You can then repeat these steps to create the blade part of the ice skate, using the smooth tool to smooth out curves. To differentiate the blade part from the sole of the ice skate, you can hold the object and press the flat button on the primary controller to open the color and material menu and use that to select a color for the object. We can also choose to change the material of the blade to a more metallic one, but this is the extent of Gravity Sketches texture and material tools.
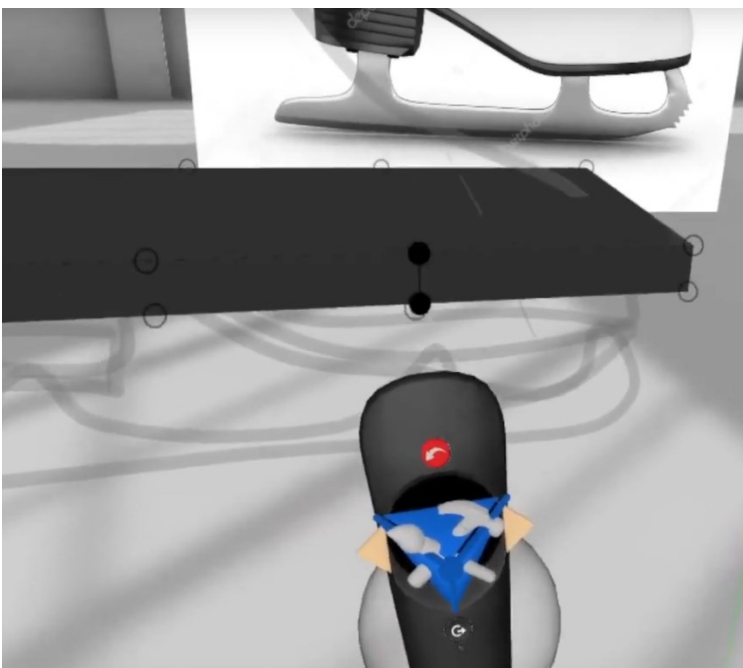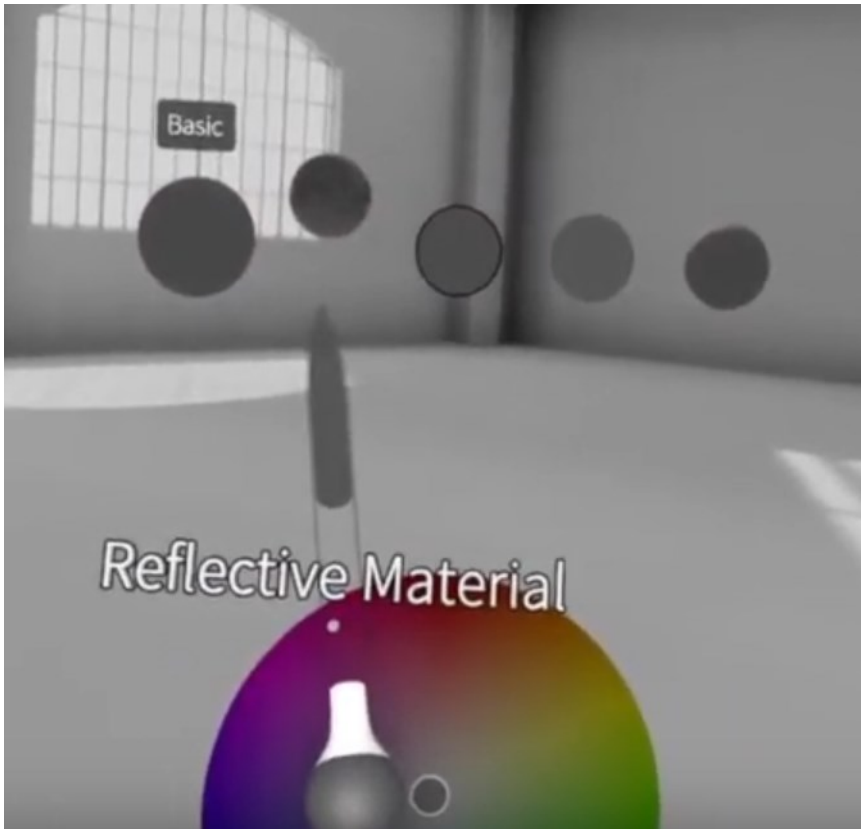

Figure 24. Changing the object material and color.

For large, curved surfaces it is preferable to use the surface tool instead, you can change to it using the tool menu. By holding down the trigger on the primary controller a line between the two controllers is created, by holding the triggers on both controllers a surface is created where this line is as the controllers are dragged. This method is used to create the body part of the ice skate in this example. Then by converting these to SubD objects you can then fine-tune the exact curvature of the surface, multiple points can also be merged to form a single, continuous surface by simply holding them close to each other. Alternatively, the SubD merge tool can be used to fuse objects together to make selecting and manipulating them together easier and quicker, especially when trying to combine objects into one, large or continuous one.
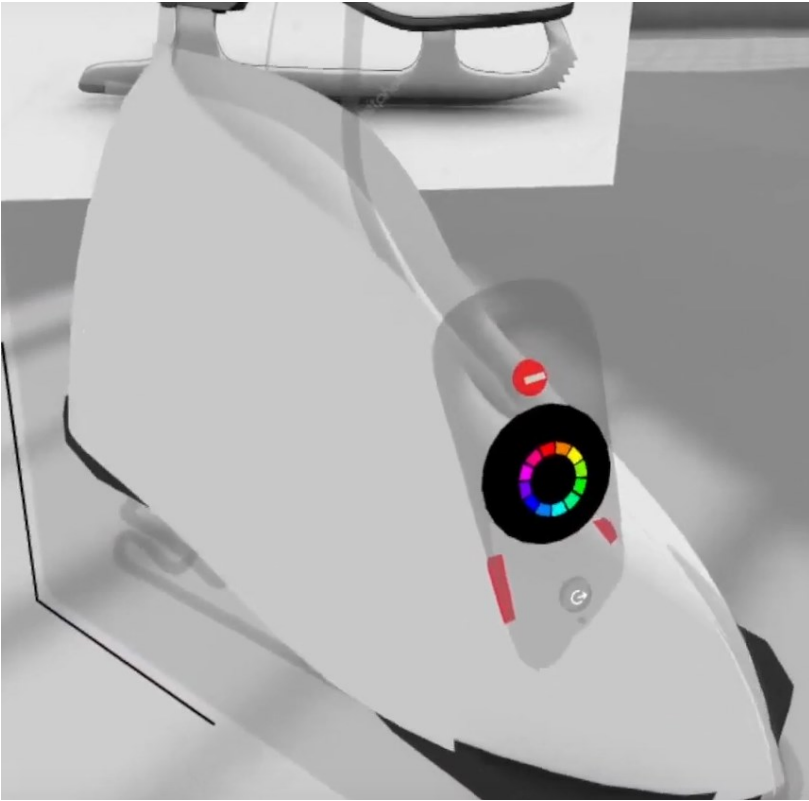
Figure 25. Using the surface tool.
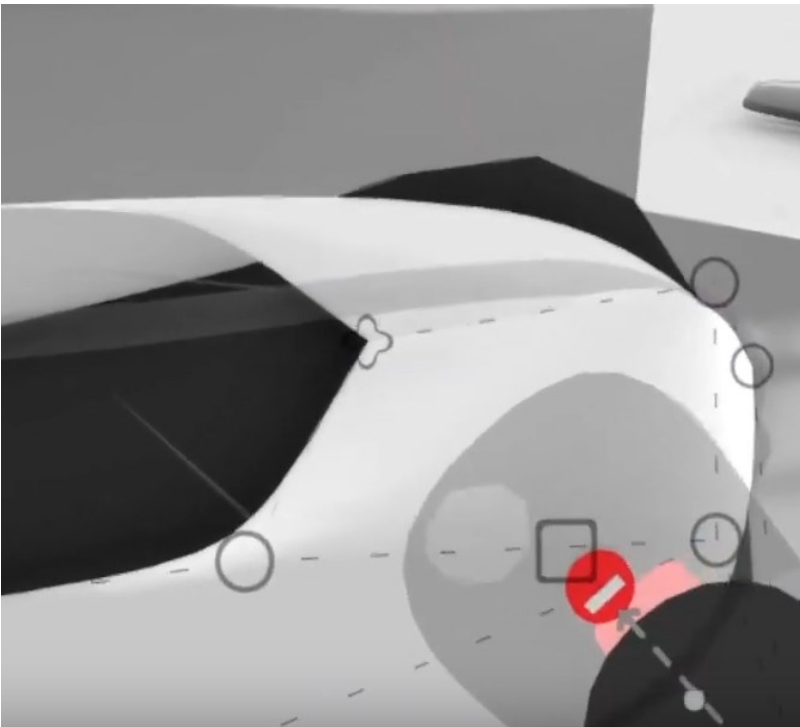
Figure 26. Fine tuning and connecting the surfaces.

After creating and fine-tuning the curves, you can create the laces for the ice skate by switching back to the stroke tool and drawing them on. Strokes do not export well into other software but are added for this example.

You can export the model by opening the menu on the non-primary controller and selecting save, then export. This will give you the option to export the model as either .OBJ, .FBX or .IGES, and which measurement to use (from millimeters, centimeters, meters, or inches). You can also go to advanced options to change how the model is exported, such as selecting the geometry type, if the groups are saved or whether the model is exported in pieces or as a single model. An example of exporting a model is seen in Figure 27, where the end result has been exported as .fbx and then put into blender.

Figure 27. End result inside Gravity Sketch.

Figure 28. End Result exported into Blender, wireframed

5 Results

5.1 Comparing the workflows

Both software follow a fundamentally similar process of 3D modeling; You add a primitive mesh and you modify it to fulfill your needs. Using reference images is simple in both software and the methods are highly similar as well.

Sketching and planning is one aspect that varies between the two software; on Blender in addition to your imported reference images, you can create annotations with the annotate tool to help sketch your creations. However, the tool is viewport and cursor dependent which makes it a bit clunky. In Gravity Sketch it is often easier to make a rough sketch, using the stroke tool, based on the reference image/s to give a rough idea of shape and volume, then start modeling around that rough sketch.

The controls of the software are vastly different from each. With Blender, you control the workspace with mouse and keyboard. As you get more experienced, you will get used to certain key combinations, which speed up the process quite a lot. With Gravity Sketch you physically move around the workspace and use the controllers to push, pull and grab the object you are working

on. This causes Gravity Sketch to feel much more natural and intuitive but causes it to lose a lot of precision in exchange, as well as making working in it over extended periods of time difficult due to the weight of the headset and controllers.

When it comes to topology, both software are able to create models with good topology, as you can see in Figure 19 and Figure 28. With Blender, you can be more flexible and precise how the edges and vertices are placed. Gravity Sketch's way to handle the topology is more automatic and determined by the program itself. Retopology is also much more manageable with Blender, especially with the modifiers it offers, such as decimate and remesh. For Gravity Sketch, there are hardly any tools specifically created for retopology.

The durations of the modeling processes for both software were surprisingly close to each other. With Blender the process took approximately 22 minutes and with Gravity Sketch the process took approximately 22-25 minutes. However, skills and experience must be considered while observing the results. The student who worked with Blender had over four years of experience with the program while the student who did the Gravity Sketch process had used the program for one and half years. For a beginner user of Blender, the process could take drastically more time as the software's learning curve is known to be steep.
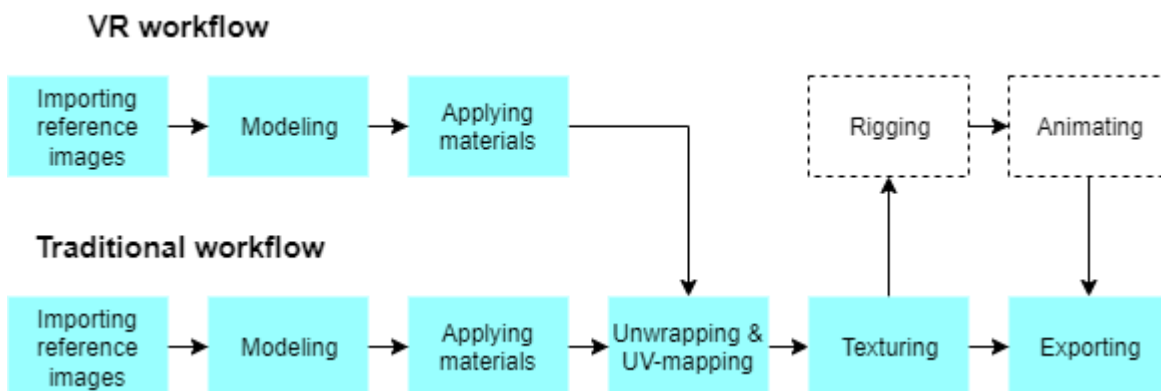
Figure 29. VR modeling process and traditional modeling process compared

Figure 29, pictured above, shows both the VR and traditional workflow of creating a 3D-object at a glance. Both the VR workflow and the traditional workflow follow same steps in the beginning. however, Gravity Sketch has its boundaries, because it doesn't have all the tools to fully produce multipurpose 3D-assets. That is why the model is needed to export to another software where it can be refined into a final product.

5.2 Interview Analysis

Both interviewees have comprehensive knowledge of different software related to 3D modeling and 3D graphics.

Both interviewees agreed that Gravity Sketch in its current state is an effective software, but lacks tools and precision required for professional use; as "Dan" (Technical Artist) explains, that "if you're doing something for games or even for film, you want a high amount of control over that geometry or a lot of tools in order to construct the geometry in a way that is nice for things like animation ".

Both believed that it has its purpose, mainly for concepting and creating basic models, but that creations still need to be moved to a proper 3D-modeling software for fine-tuning afterwards. This is made worse by Gravity Sketch not having proper support for anything else than general modeling tools.

Gravity Sketches collaboration tools were also well received, both interviewees believing the system to have potential, mostly in early stages of projects. Especially "Cris" (Industrial Designer) believes that "it would just allow you to work with your coworkers even better and just understand each other a little bit more and be able to riff off of things a little bit more". At those early stages He believes the system would allow artists to collaborate on concepts and balance each other's styles.

During their interview Dan was asked about the biggest issue with Gravity Sketch (and VR in general), he responded that "If your perspective is to replace it or use it as a modeling tool, it is not so ergonomic". VR in general has problems with ergonomics: modeling work often takes hours upon hours, standing around and reaching with your arms will tire you out over a longer period, as the controllers and headset aren't really that light.

When asked about the best uses for VR technology, Dan mused that sculpting and texturing would be interesting to see in VR, since you could reach out and carve or paint directly with your hands, playing directly into VRs strengths. Cris believed that VR should be used more in general, but especially for teamwork and communication.

5.3 Ethicality

Both interviewees agreed to the interview after being given ample notice and were also explained the interview's purpose and that they will be recorded and transcribed for use in the thesis project. No personal data has been used without consent, and all communications have been kept private and secure, and as little identifiable data as possible has been used.

Data has been collected following good data collection policies from reliable and publicly accessible sources. Original sources have been cited and referenced according to APA guidelines, without changing the meaning or intention of the original text. All research data is saved securely and managed following a pre-made data management plan.

5.4 Reliability

For our sources, we sought out to use mainly direct sources such as manuals or websites for the different software, where applicable. In addition, we focused on using sources that were major publications or from industry experts, or other credible sources, as such information was sought out first from software publishers when possible then through internet searches.

The interviews were conducted with interviewees who both had years of relevant industry experience. The interviews were semi-structured and without leading questions.

The software comparison and example workflows were done by hand, utilizing the researchers' combined knowledge on our respective software.

6   Conclusions

6.1   Outcome of the Thesis

In general, the results of the thesis were quite similar to the initial hypothesis:

What are the current states of Modeling and VR technology?

3D-Modeling in general has had major improvements over the past few years, with new technologies and methods improving the result and process, while making software more versatile (and accessible). For example Blender has been evolving massively with its new features and the amount of users is larger

That said, the process/pipeline has stayed relatively similar over this time, with only recently 3D-Scanning and Procedural Generation starting to enter the mainstream, drastically changing and streamlining the creating process.

VR technology on the other hand has had major improvements over the past few years, with home headsets becoming a lot more accessible and affordable for normal users, and companies starting to develop more software (and hardware) to use in a VR setting.

Is VR technology advanced enough to replace traditional technology?

After doing the research about the possible solutions for the VR modeling software and executing the 3D modeling processes with both traditional and virtual reality modeling software, the outcome was that the current VR technology isn't advanced enough to replace traditional 3D modeling software's workflows and processes. The claim is supported by the higher expenses of virtual reality equipment and 3D models quality, which isn't drastically different to traditionally created 3D models. Many 3D software include features which are non-existent in VR software, such as rigging and animating tools.

Is VR technology advanced enough to be used alongside traditional technology?

While VR technology isn't able to completely replace traditional software, it still has uses alongside traditional software, specifically in parts of the process that can play to VRs benefits: where you can use your hands and the space to your advantage. Examples of these would be: during the sculpting process, where you could use your hands to edit the model like clay, or during the texturing/texture painting process.

How would one implement VR into a modern modeling workflow?

Companies already use VR for various purposes, ranging from training to communication. Gravity Sketch, or other applicable VR Modeling software, could be implemented primarily in the earlier stages of production, where accuracy and precision is not quite as important as in later stages of production, due to its low accuracy compared to traditional software, for example to create a raw model to then be improved upon in other software, such as Blender or Maya.

Another use case would be in the early concepting stages, where multiple concept artists/modelers could use Gravity Sketches collaboration tools to plan or create concept art together, that

could then be passed on to modelers to use in traditional software. Alternatively, the same feature could be used mid-production to allow other artists to give ideas or suggestions by directly drawing on an imported model, or even after the process is over to give feedback.

The main issues with implementing a program like Gravity Sketch are the cost, time to train users and the ergonomics of VR Hardware; VR hardware is still relatively expensive, and is not comfortable for long term use, as modeling and concepting can take hours upon hours. In addition, the time to train users to use Gravity Sketch, nor new software in general, is not a negligible amount of time. While Gravity Sketch itself is relatively simple to use, training artists who are used to using traditional software can be a time-consuming process. On the other hand, people who are not used to traditional software (or can't use them in the first place) might find Gravity Sketch much more manageable.

6.2 Significance of the Study

The field of VR is slowly being recognized as important by more and more companies, as the technology improves and becomes more versatile; more and more companies are starting to use (and develop) tools for VR. Especially as remote work and automation is becoming more prevalent, VR can provide a great access point for employees and companies: allowing users to work from home while still feeling like they're in the same space, or to control machines remotely while seeing what the machine sees via VR headset.

VR software has had, and will continue to have, an impact in the modeling industry in general, especially as the field is still growing and evolving. Gravity Sketch specifically is interesting due to its status as a 'free but effective' VR modeling software with features that would allow teams to work together and collaborate much easier than they currently do.

6.3 Discussion

6.3.1 Companies Implementing VR Technology

Companies have been using VR technology more and more over the past few years and the technology has been used in more and more fields in general, especially over the 2019 pandemic – not just for mechanical or training purposes but also just for communications, such as meetings, and the use cases will continue to expand into the foreseeable future, especially as the technology advances and becomes more accessible. Especially since companies in general are moving towards

remote work, and generally using more AI and automation, VR can provide a good access point for employees in the future.

6.3.2 Future of AI in 3D world

For a few years now, artificial intelligence has taken huge steps when it comes to generating images based on prompts people feed to the AI. Different AI programs, such as MidJourney and Stable Diffusion, can produce high quality concept art within a few minutes, which has raised questions about the meaning of an artist. Is there really a need to hire an artist when a machine can create comparable products for less money and less time?

Even though most of the progress with AI art is related to 2D, in future there may be much more progress with 3D areas. While the thesis revolved around virtual reality modeling software and their possibilities with sketching and concepting, an AI based tool for creating 3D concept art could be closer than one can think.

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Appendices

Appendix 1. Interview Structure

Interviews were conducted as semi-structured interviews with a preset theme and frame. The following framework was used:

- Introductions
- Their Background

- Their relationship and experiences with VR

    - Have they used VR? (Or own one?)
    - Their experience level with VR?
    - Explain as necessary.

- Explain Gravity Sketch and its features to them, asking for their opinion.

    - Explain its features.
    - Compare it to traditional software, say blender.
    - Ask for their opinion on it and how it could improve.

- Understanding their/their company's modeling/work pipeline.

    - Get a rough understanding of how modeling works in a professional setting.
    - Find out if this is similar to other companies/pros.
    - What are the points that slow down the pipeline/that could be improved?

- How GS or similar VR software could be implemented in the pipeline.

    - Knowing both GS and their pipeline, how would they use it?

    - How could a company implement it?
    - Would a company consider using VR?
    - Other ways for a company to use VR?

- If the company is already using VR, what are they using and how did it change them?

    - How is the company using VR?

    - How did they decide to use it?
    - How has it changed the company?
    - Have they considered using it for modeling?
    - How could they use it more?
    - (See previous theme for more ideas)

- Speculation on the future of VR (if have time)

    - VR/AR is becoming more accessible, give examples
    - What kind of software/uses would they like to see?