

Graduation Report

Report by Oliver Harrison

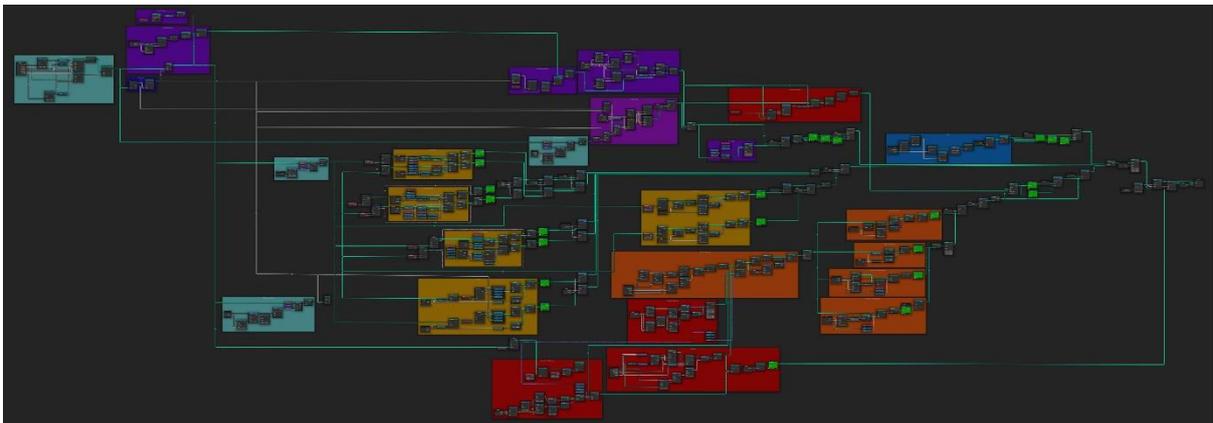
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Summary

The Procedural Interior Showroom Generator is a tool made using Blender geometry nodes to assist the Letink Design 3D team in creating virtual showroom environments using procedural modelling.

To define the design theory behind the Procedural Interior Showroom Generator, the main research question was formulated:

- How can one develop a node-based procedural tool that can create effective virtual showroom environments, so that Letink Design can save time and money when creating iterations based on the needs of different clients?

To answer the main research question, it was divided into four separate sub-research questions in [Section 2.4](#).

The first research question identified Blender geometry nodes as the procedural modelling platform that would be best suited to the project.

The second research question explored existing virtual showrooms and identified what elements make them successful. To create a memorable yet effective and affordable virtual showroom, a balance must be found between complexity and functionality. A showroom needs to be unique, whilst maintaining the feel of a classic showroom experience.

Sub-research question three explored the benefits of procedural modelling over manual modelling workflows. Testing sessions also revealed that manual navigation of a complex node tree, supported by an extensive colour-coded user manual was preferred by the users.

Lastly, to answer the fourth research question, the results of both testing rounds were combined with client feedback and research for the second research question. This guided the development of the tool and the many customisation options that were included.

The findings of all the sub-research questions were combined into an answer to the main research question:

- Develop a procedural node-based tool using Blender geometry nodes, that provides the user with an efficient way to create a large variety of effective virtual showroom environments.

The results of all of these research questions were integrated into the Procedural Interior Showroom Generator's design. The tool is made entirely of procedurally generated geometry using Blender geometry nodes from version 3.1+. There are over 80 customisation options per room and multiple different rooms can be connected through procedurally generated tunnels.

A post on blenderartists.org was made showcasing the tool and its possibilities, as well as documenting some of the work behind a geometry node project of this scale:

<https://blenderartists.org/t/procedural-interior-showroom-with-geometry-nodes/1377390>

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1. Introduction

Virtual showrooms and other interactive online exhibition tools have become increasingly popular within the retail industry, particularly during the last few years. COVID-19 has forced brands and retailers to adapt to new rules and regulations, accelerating the need for this genre of virtual showroom product. Brands like Vredestein ([Apollo Vredestein BV, 2020](#)), Toyota ([Toyota Kirloskar Motor Private Ltd](#)) and Geberit ([Geberit](#)) make use of virtual showrooms to show off their products in an online exhibition environment.

Letink Design has been working on a virtual showroom product to pitch to some of their many clients, such as GEA, Nijburg, Itho Daalderop, etc; to take advantage of the increasing demand for ways to present products online.

Such a product comes with a major drawback, creating complex 3D scenes is very time-consuming. The brands it is aimed at all expect their own unique experience, with their desired layout, colour palette, logos, and varying requirements depending on the size and aesthetics of the displayed products. An experience that is the same as that of another brand that has purchased the same virtual showroom product is undesirable. This means that different scenes need to be created per customer using a manual modelling workflow, reducing the possible profit for Letink.

“Procedural modelling is an alternative approach to standard modelling using software like 3D Max or Maya. Procedural models are more mathematical descriptions and formulas than meshes.” ([Pitonakova, L., 2008](#)). Since procedural modelling is complex with a steep learning curve, many small companies do not have the time or funds to research the subject. A procedural model would allow for quickly making iterations based on different client needs, making the price of a virtual showroom environment more affordable.

This report describes the development process of a tool meant to assist 3D developers in creating personalised virtual showroom environments, using a procedural workflow.

The report will begin by defining the project’s objectives through the definition of a problem statement and research questions.

Following this, the report will describe the design phase of the tool, with justification for the design choices that were made.

During the design phase, research was conducted to gain insight into existing projects and workflows. Based on this research, the production plan was formed to increase the chances of a successful result.

With the design in place, an iterative production phase began. This report describes the development process and the difficulties that were encountered.

Finally, the end product will be presented and conclusions will be made.

2. Project definition

2.1 Problem definition

The main problem behind this project is to reduce the cost of the virtual showroom product being produced at Letink Design. As well as producing a procedural modelling workflow for the virtual showrooms, the skills and knowledge gathered can be used in future projects. Procedural modelling workflows have endless applications and are being integrated into 3D development pipelines more and more as “the push for better, more detailed, extensive and visually convincing virtual worlds” ([Smelik, R.M., Tutenel, T., Bidarra, R., Benes, B., 2014](#)) increases.

The **reason** for the project is the following:

- To optimise the workflow for Letink in order to facilitate iterations of a virtual showroom environment for different clients with different needs while developing the knowledge needed for procedural modelling workflows.

To realise the goal of making the virtual showroom product more profitable and more affordable, preliminary research into procedural tools and workflows was undertaken to identify the following **problem**:

- Manually modelling virtual showroom environments specific to varying client needs is expensive and time-consuming, but the complexity and steep learning curve of procedural modelling techniques make the topic difficult for small companies to research.

The **solution** is the following:

- A procedural tool that helps with modelling virtual showroom environments with customisable parameters that can be adjusted to the needs of different clients.

2.2 Subject research

The solution defined in [Section 2.1](#) lacks specificity. This section defines the solution more clearly. To do so, research into procedural workflows, their existing applications in the 3D industry, and the limiting factors of the workflow was done.

Research topics included:

- The history of procedural modelling workflows and the different methods of applying them.
- Common uses of procedural tools in the 3D industry in recent years.
- The strengths and limitations of a procedural modelling workflow, compared to manual modelling.
- Existing procedural tools for creating assets

Procedural modelling has been an active research topic for at least 30 years. This research has mainly been related to programming, mathematics and engineering; very complex subjects. One example of this is L-systems, created by Aristid Lindenmayer in 1968 as a way to formalise patterns of bacteria growth. “L-systems are used today to simulate organic growth in computer graphics, with applications in plant development, procedural content generation, and fractal-like art” ([Santell, J., 2019](#)).

More recently, tools have and are actively being developed to give artists and other individuals without in-depth technical knowledge access to such a workflow. One example of this is CityEngine, a 3D modelling software for creating huge, interactive and immersive urban environments in less time than traditional modelling techniques. ([Esri R&D Center Zurich, 2008](#)). This tool employs the L-systems mentioned previously to generate city layouts and the building geometry that fills them and is one of many examples of applications that have been developed to procedurally create 3D geometry.

Furthermore, procedural systems can be seen in many video games, often for terrain generation. Examples of this are Minecraft ([Mojang Studios, 2011](#)), Terraria ([Re-Logic, 2011](#)) and No Man’s Sky ([Hello Games, 2016](#)), all of which generate terrain and structures randomly, but are based on a set of rules so that the structure is consistent and cohesive. As well as terrain, procedural generation has been used for creating other content in games with the example of the Borderlands series ([Gearbox Software, 2009](#)) where the weapons are generated procedurally, making almost 18 million possibilities ([Yin-Poole, W., 2012](#)).

The examples of procedural modelling that have been discussed so far have had very specific applications, and have been developed by software engineers or game programmers. Creating such a tool would be very challenging and unfeasible due to the lack of existing code and mathematics knowledge. An alternative method of creating procedural assets is presented by the modern 3D computer graphics software, namely Houdini ([Side Effects Software Inc., 1996](#)) and Blender ([Blender Foundation, 1994](#)).

Houdini is unique compared to most 3D software in that every action is stored in a node. This node-based system creates a procedural workflow, as at any step in the 3D pipeline, old versions can be viewed, changes can be edited and new nodes can be added. Houdini is built around this iterative workflow and allows for the creation of tools with fully customisable parameters, much like the CityEngine tool mentioned previously, but all possible within the 3D software and accessible without programming knowledge.

Blender is a more standard 3D software at its base, but recent development has introduced a system called Geometry Nodes. This system uses a similar node-based setup to Houdini and can be used to create procedural tools with customisable parameters in almost the same way. This combined with Blenders' previously existing modifier system allows for an iterative and non-destructive modelling workflow.

These are powerful tools that make it possible for artists to integrate procedural modelling into their workflow without much scripting or other technical knowledge. These tools still have steep learning curves, in particular Houdini, and require a considerable understanding of 3D modelling alongside mathematics, to create complex tools.

Procedural modelling has many exciting possibilities, particularly in terms of data amplification, described as “a simple set of input parameters or a few generation rules of the procedural model yield a wide variety of models.” ([Smelik, R.M., 2014](#)). It does however come with many limitations and challenges compared to manual modelling. This is described once again by R.M.Smelik in his 2014 paper: “despite promising a high productivity gain, a compact representation, and a seemingly endless variation in content, most current procedural modelling methods still do not offer a suitable alternative to manual modelling. The main reason is the poor controllability of most procedural models.” ([Smelik, R.M., 2014](#)). Though this statement was true in 2014, the last 8 years have seen a growth in popularity of this type of workflow. This can be seen through the growth in popularity of Houdini and its introduction into more mainstream 3D software such as Blender. Furthermore, procedural workflows have seen an increased implementation in game development with the integration of procedural tools in Unity ([Unity Technologies, 2005](#)) and Unreal Engine ([Epic Games, 1998](#)). An example of the Houdini integration in Unity is shown in a video presentation by Luis Garcia ([SideFX Houdini, 2017](#)) where he showcases his use of procedural modelling for game development. Rather than creating the entire model procedurally, he uses assets created with typical 3D modelling methods and uses Houdini to turn them into procedural assets that are controlled by adjustable curves. This bypasses some of the limitations of procedural modelling by stringing together modular assets and ultimately leaving control over their placement and shape to an artist. This avoids the need to manually create models for each application as the procedural asset can be used for whatever shape or size is necessary, and reduces the complexity required for the system to yield an attractive result.

In conclusion, procedural modelling is a growing workflow for creating 3D assets and is most powerful when large quantities of similar assets are required. Though procedural modelling has long been tied into complex mathematics and scripting, it is more recently being integrated into artistic workflows in software like Houdini and Blender. This presents a great opportunity for learning about node-based procedural workflows and to create tools that can solve the problem presented by Letink Design for making iterations of virtual showroom environments.

Following this research, the **solution** suggested in [Section 2.1](#) was updated:

- A node-based procedural tool made in Houdini or Blender to help with creating virtual showroom environments that can be customised to the needs of different clients.

The changes clarify that a node-based procedural workflow will be used, such as Houdini or geometry nodes in Blender. The solution is now more specific, and detailed market research can be made.

2.3 Main research question

Following the definition of the problem and solution in [Section 2.1](#) and [Section 2.2](#) respectively, the main research question was constructed:

- How can one develop a node-based procedural tool that can create effective virtual showroom environments, so that Letink Design can save time and money when creating iterations based on the needs of different clients?

The **goal** for this project is “so that Letink Design can save time and money”.

The **problem context** is “when creating iterations based on the needs of different clients”.

The **product** that will be made to accomplish the goal is “a node-based procedural tool”.

The **requirements** for this product are “can create effective virtual showroom environments”.

2.4 Sub-research questions

To make the main research question more manageable, sub-questions were formed.

To define appropriate sub-questions, the main research question was broken into elements that could be clarified further:

- How to develop a node-based procedural tool?
- How to model virtual showroom environments?
- How to save time and money?
- How to encompass the needs of different clients?

2.4.1 What platform/procedural workflow should the tool be made with?

As mentioned in [Section 2.2](#), the main procedural modelling platforms that will be investigated are Blender geometry nodes and Side FX Houdini. Despite this, research was done into several other alternative platforms that allow for procedural modelling. To decide

on the platform that would best suit the project, a case study was conducted using SWOT analysis to compare the options:

The different platforms for procedural modelling that were investigated are Blender geometry nodes ([Blender Foundation, 1994](#)), Side FX Houdini ([Side Effects Software Inc., 1996](#)), Rhinoceros Grasshopper 3D ([McNeel, R., 1980](#)), DynamoRevit ([Fox, P., 1958](#)), and Python scripting ([Python Software Foundation, 1991](#)).

The full contents of the case study can be found in [Appendix 1](#).

Case Study - SWOT analysis of procedural modelling platforms - OliverHarrison444399.docx

Following the SWOT analysis, it is clear that DynamoRevit, Grasshopper 3D in Rhinoceros, and other CAD or BIM software, despite offering several forms of procedural node-based modelling workflows, are not suitable platforms for this project. These software packages are intended for complex and realistic design for real-world applications. More suitable platforms for building a procedural tool to create environments for virtual showroom applications are Blender or Houdini.

Blender geometry nodes and Houdini are both very promising platforms for procedural modelling within this project, with varying strengths, weaknesses, and similarities. Further investigation into these options was needed to make a final decision.

As well as this analysis, research was done into the general popularity of the different platforms. Data on the volume of users for each platform is not readily available but estimates have been made. Andrew Price, CEO of Poliigon and creator of Blenderguru used the available data to make estimations on how many people are using the 4 main 3D platforms designed for media and entertainment: Blender, Autodesk (3DS Max, Maya, and Shotgun), Maxon, and SideFX Houdini ([Price, A., 2020](#)).

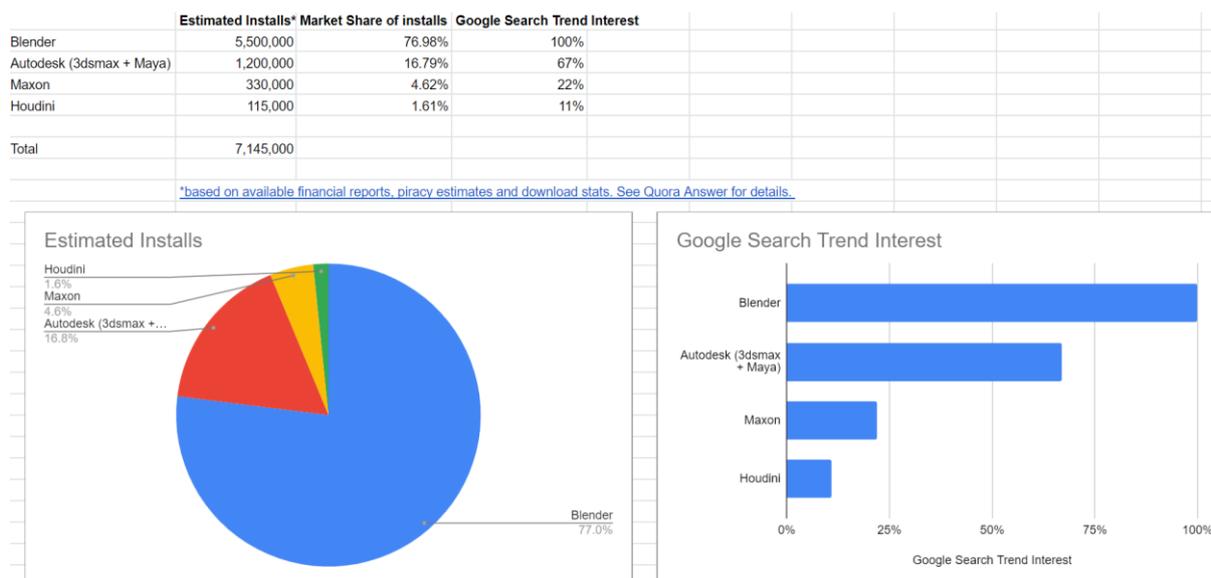


Figure 1: 3D software installation estimates

As seen in Figure 1, estimated figures show installations of Blender to be 5.5 million compared to 115k for Houdini. Since Blender is free, higher popularity is expected. Such a large difference, however, makes it clear that Blender is not only more available due to the cost, but also due to the community around it. Blender has a huge and constantly growing number of sources for learning and guidance, making it more accessible to learn than Houdini.

To prevent confirmation bias by using only one source, Google trends (Google, 2006) was used to take the investigation further. Interest over time was compared both in both Google searches and YouTube searches over the past 5 years between the 4 platforms being analysed.

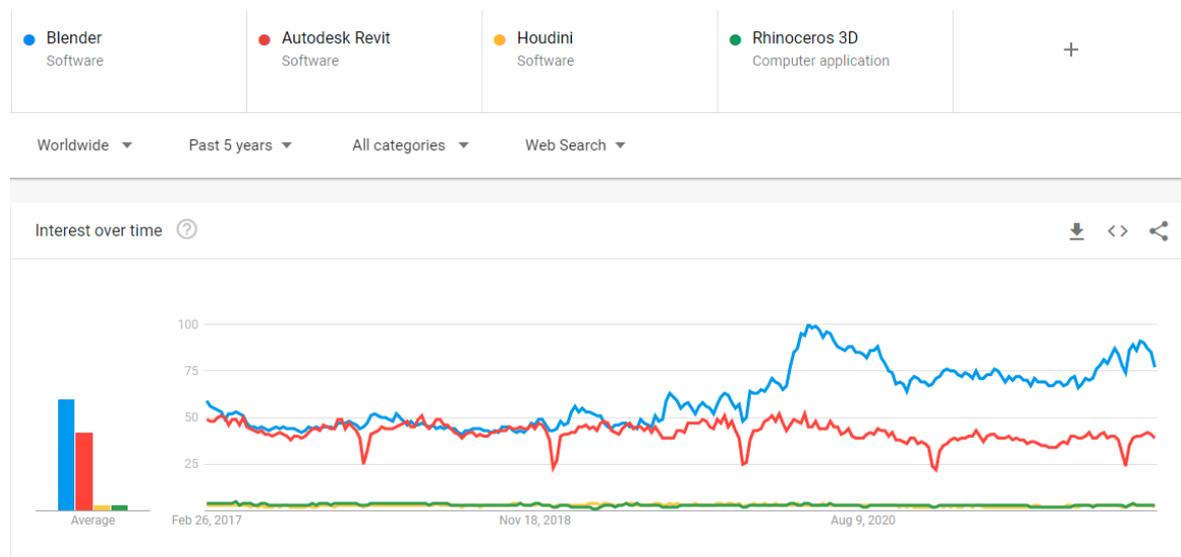


Figure 2: Web search interest over the past 5 years

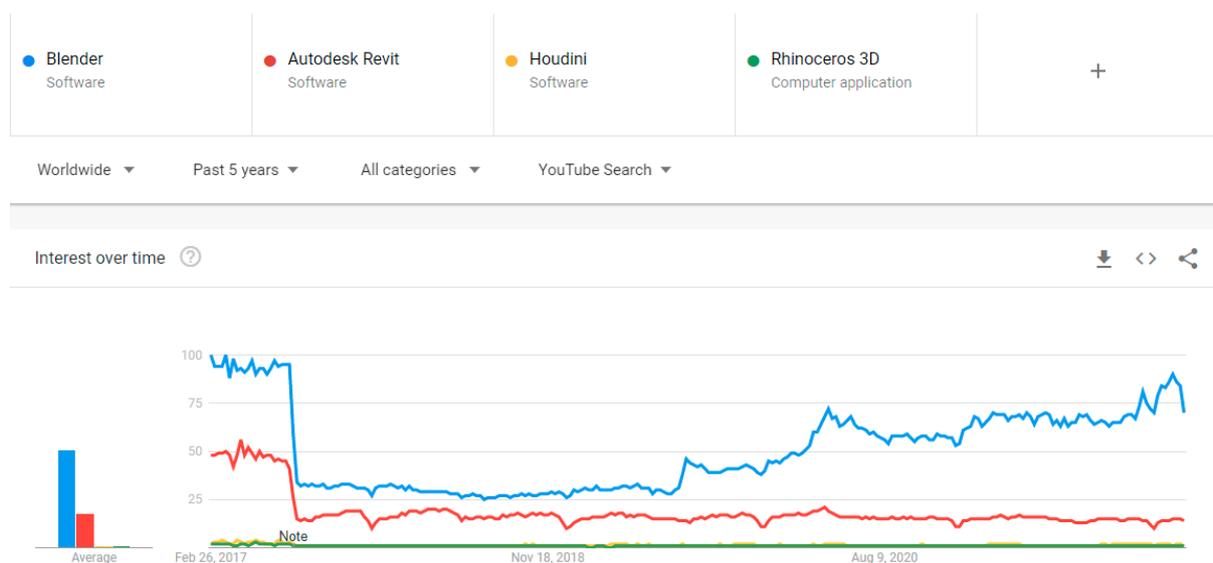


Figure 3: YouTube search interest over the past 5 years

The statistics in Figure 2 and Figure 3 once again show the clear popularity of Blender over other 3D platforms, Web searches showing interest in downloading the software, and

YouTube searches showing interest in tutorials and other learning content. This, as well as a consistent increase in popularity of the platform over the 5 years, shows that Blender is by far the most popular choice of 3D software. As a result Blender will be able to provide a platform with the most sources for referencing existing work, learning new workflows, and receiving feedback.

To decide between Blender and Houdini several factors must be considered. If functionalities are considered, Houdini is the best option, however not by much. To extend the research, a selection of procedural modelling YouTube tutorials were followed, both for Houdini and Blender. Following this, it was possible to create simple proofs of concept for procedural virtual showroom environments using both software. As seen in Figure 4 and Figure 7, the resulting geometry was identical.

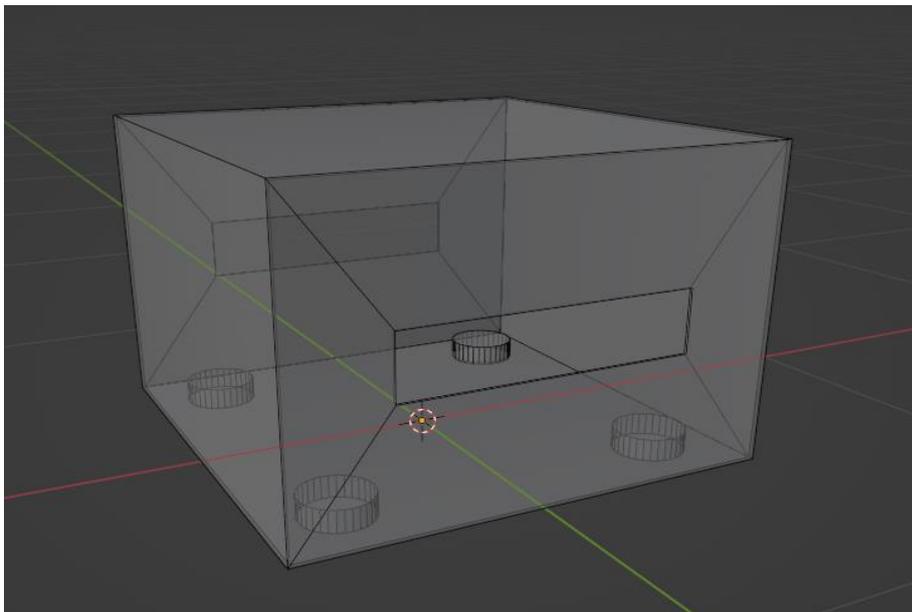


Figure 4: Blender proof of concept default output geometry

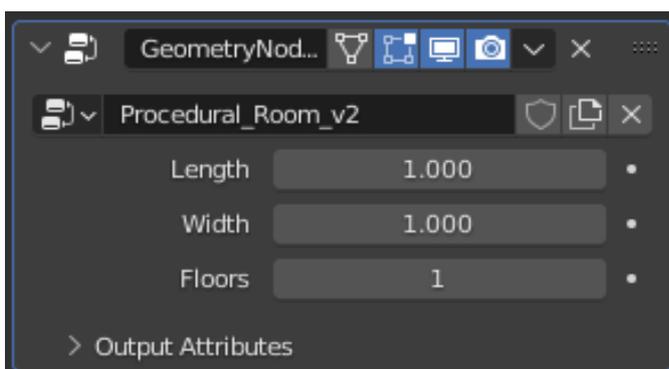


Figure 5: Blender proof of concept controls

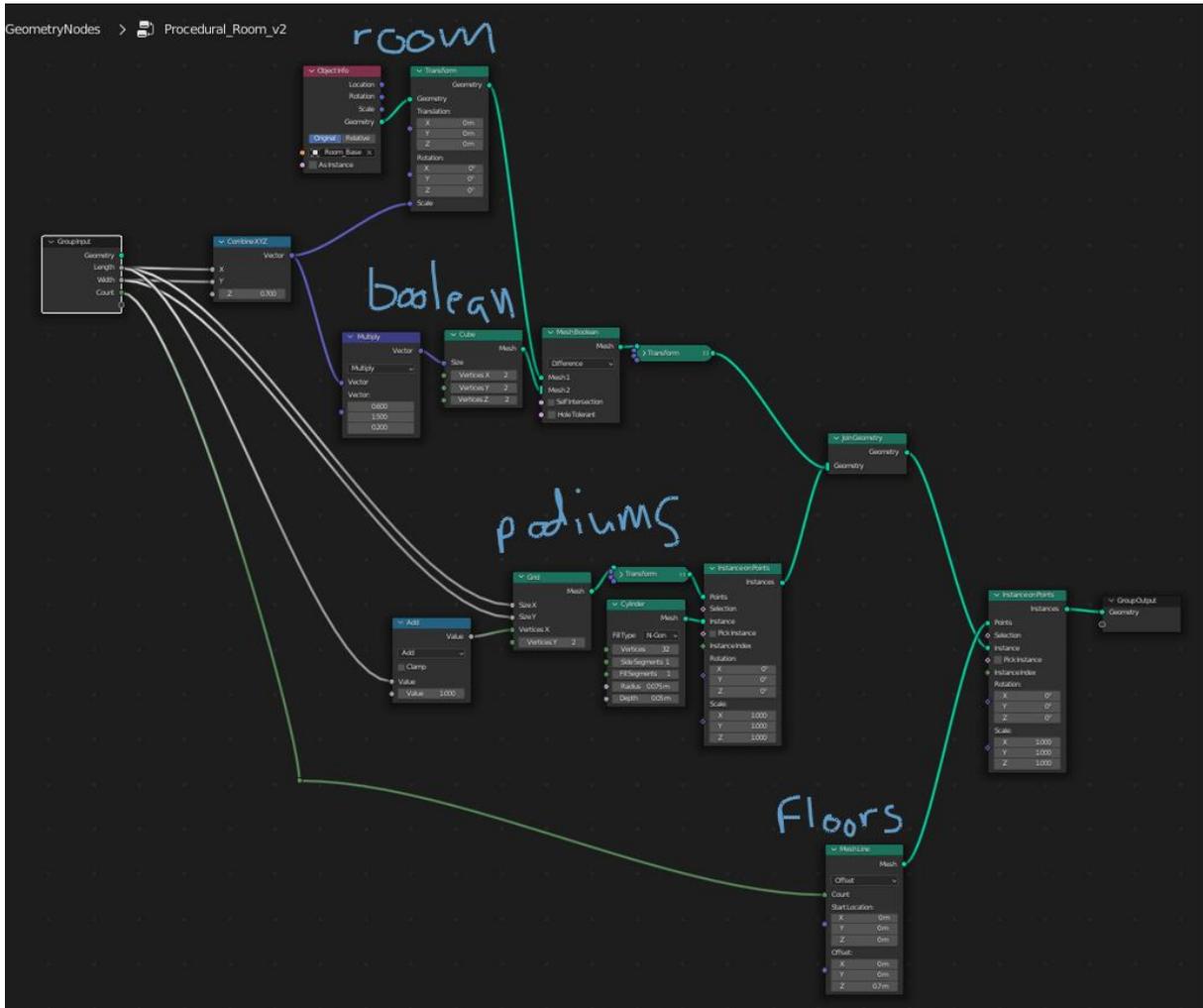


Figure 6: Blender proof of concept node-setup

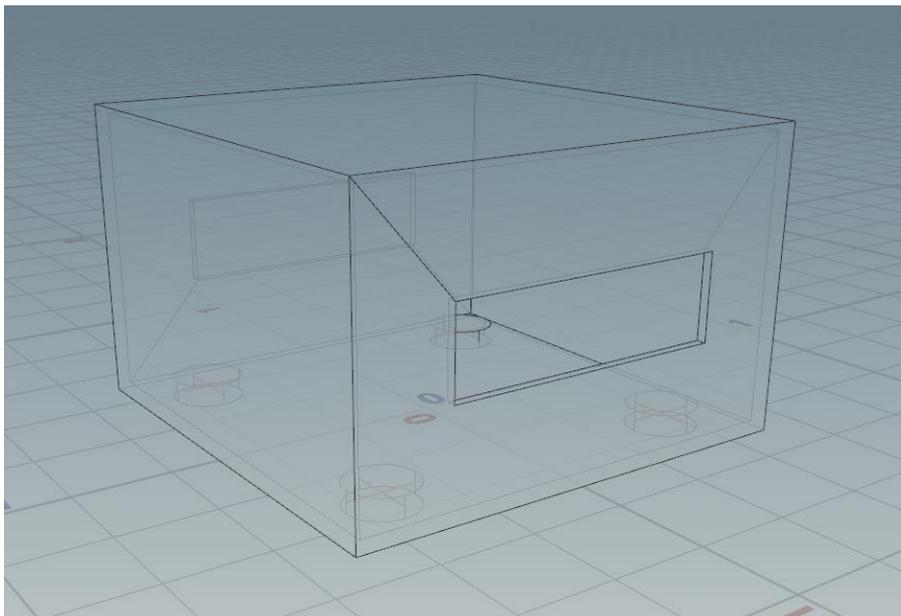


Figure 7: Houdini proof of concept default output geometry



Figure 8: Houdini proof of concept controls

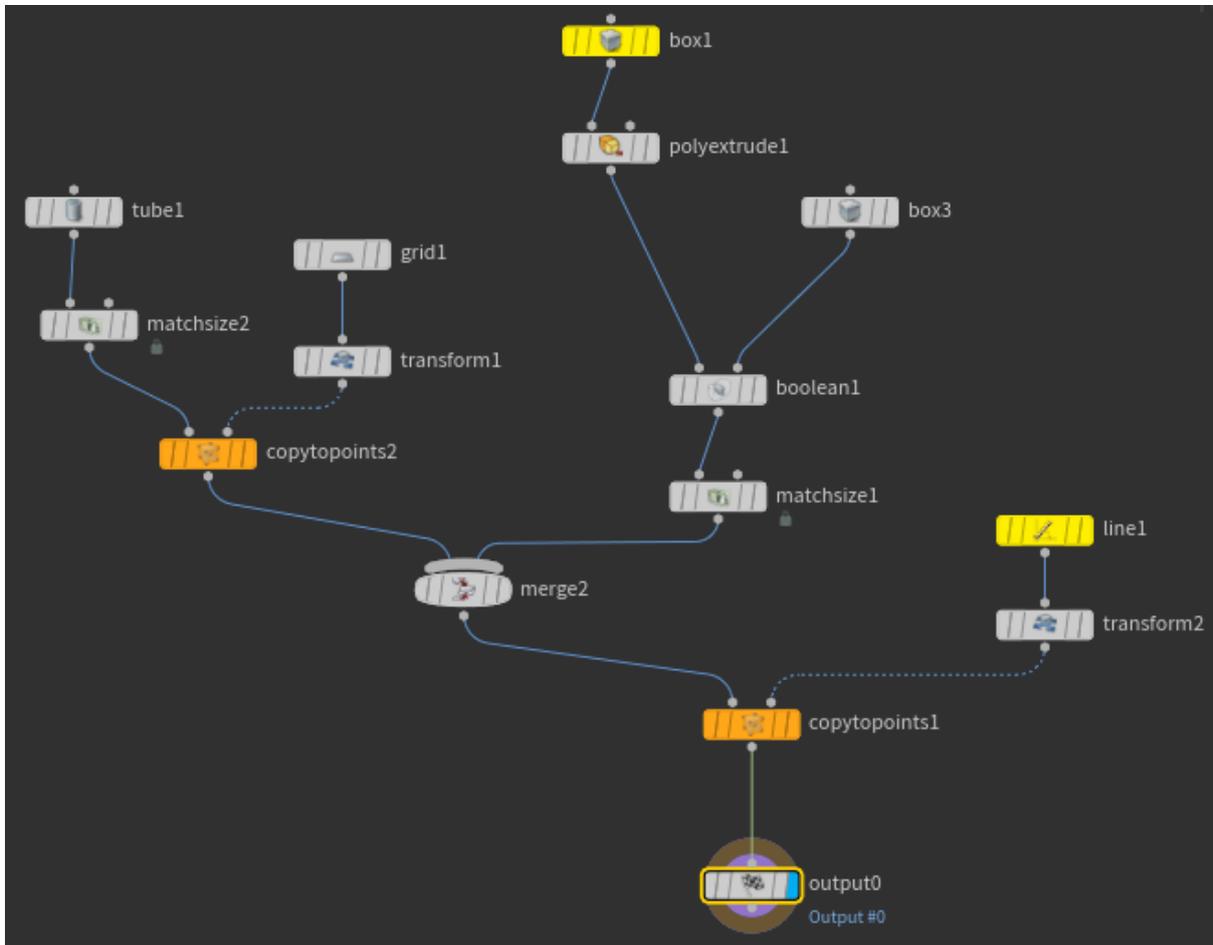


Figure 9: Houdini proof of concept node-setup

Following this experiment, a lot was learnt about using the procedural workflows in both software packages. Both software's allowed for the set up of easy to use customisation sliders (Figure 5 and Figure 8). The only difference between the software for this example was that the Houdini node setup (Figure 9) was more compact than Blender (Figure 6), due to the ability to do maths and link parameters to each other within the nodes, compared to the need to use maths nodes and connect them to the Group Input in Blender. This compact node tree appears more straight forward but I found that the visualisation of every connection in Blender could be easier to understand and follow.

This experiment was a relatively simple setup but explored many of the features that both platforms provide for creating procedural tools. Both platforms allow similar workflows for creating procedural geometry, catalysing the decision to use Blender for this project.

Ultimately, Blender geometry nodes were chosen as the platform for creating this procedural tool. Geometry nodes have recently been expanded a lot and rapid development continues for them, making them a great alternative to Houdini. During research, countless very

impressive projects created with Blender geometry nodes since the release of version 3.0 in December were discovered. The possibilities presented by these projects reassured that this workflow would not be limiting for the project. As well as being able to provide all of the tools needed to create a complex procedural environment, Blender is free and it is a software that myself and most of the 3D team at Letink have significant experience with, leading to a clear decision on this workflow for the project.

2.4.2 What makes a virtual showroom environment a successful marketing tool?

As mentioned in [Section 1](#), virtual showroom experiences are a growing market mainly due to the implementation of rules and regulations to reduce the spread of COVID-19, but also because of an increased desire to make modern technology a part of marketing by all forms of brands. Technology allows marketing campaigns to be more personalised, immersive, and able to reach a wider audience, with over 50% of the world's population being connected via the internet ([Hannay, F., 2019](#)). To get a better understanding of the virtual showroom market and what makes a virtual showroom an effective marketing tool, qualitative desk research was done into existing examples:

Vredestein Experience Centre is a virtual showroom advertising the Vredestein tyre brand ([Apollo Vredestein BV, 2020](#)). As seen in Figure 10 and Figure 11, it consists of a large futuristic exhibition-like environment with multiple rooms of impressive scale. It has a very unique and distinct style, and the immense depth of the scenes ensures that the viewer always has something to look at. With there being a lot to look at, the user's attention can be drawn away from important features being advertised, and instead, explore the many details of the environment. In most cases, however, important features such as pathways, tyre displays, and bright posters or screens can grab the user's attention. The 3D scene of this virtual experience is a great example of what a high-quality virtual showroom could look like, providing a unique and interesting scene for users to explore. This creates a memorable experience and acts as a great online marketing space. Despite these good qualities, creating a scene with this level of complexity will be very time-consuming and as a result very expensive to create and make iterations of.

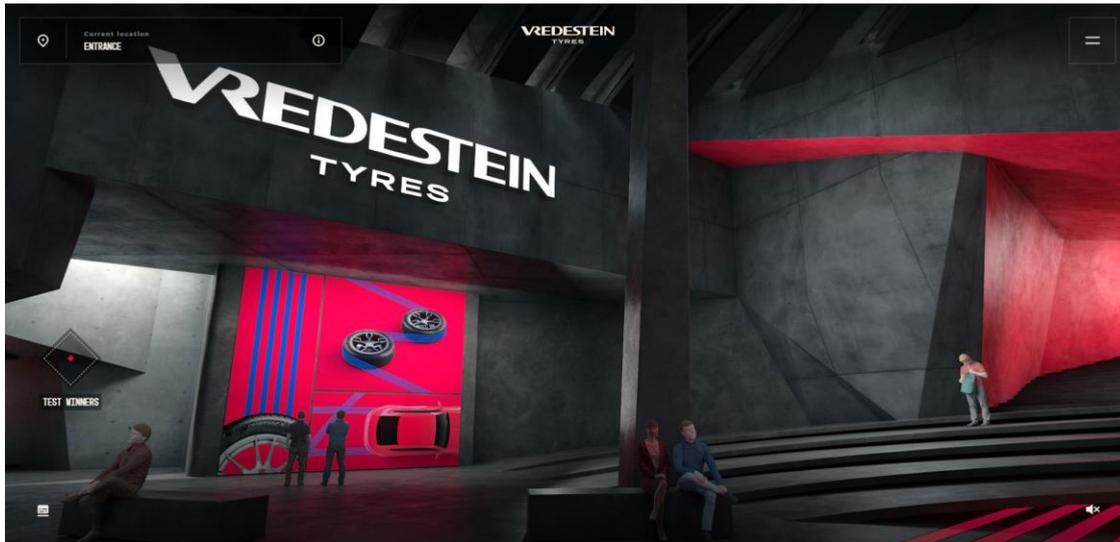


Figure 10: Vredestein Experience Screenshot 1

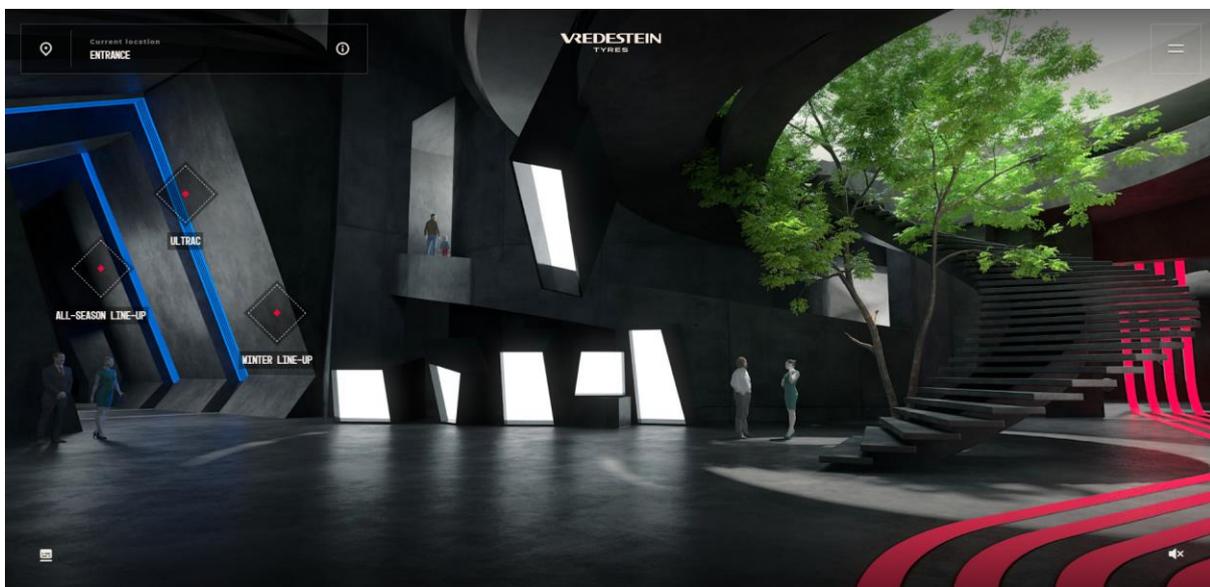


Figure 11: Vredestein Experience Screenshot 2

Toyota Virtual Showroom is advertising Toyota's current selection of cars ([Toyota, n.d.](#)). This example of a virtual showroom is more simplistic, consisting of one large exhibition room with cars lined up on each side (Figure 12). The web application also has a 360° viewer for each car that can be loaded by clicking a button above each vehicle. This example has a more realistic but less interesting environment to look at, with much fewer possibilities for exploration. This keeps the viewer focused on the vehicles being displayed but makes the experience less memorable than the Vredestein Experience for example, as is clearly shown through the survey results in [Appendix 5](#). Despite the environment not being particularly exciting, the 360° viewer allows the viewer to look at the vehicles in great detail, providing both an inside and outside view, with options for various backgrounds, and the option to activate the lights of the vehicle or to open the doors. These functionalities are great and provide the user with detailed insight into the product, however, are not a part of the environment design being researched.

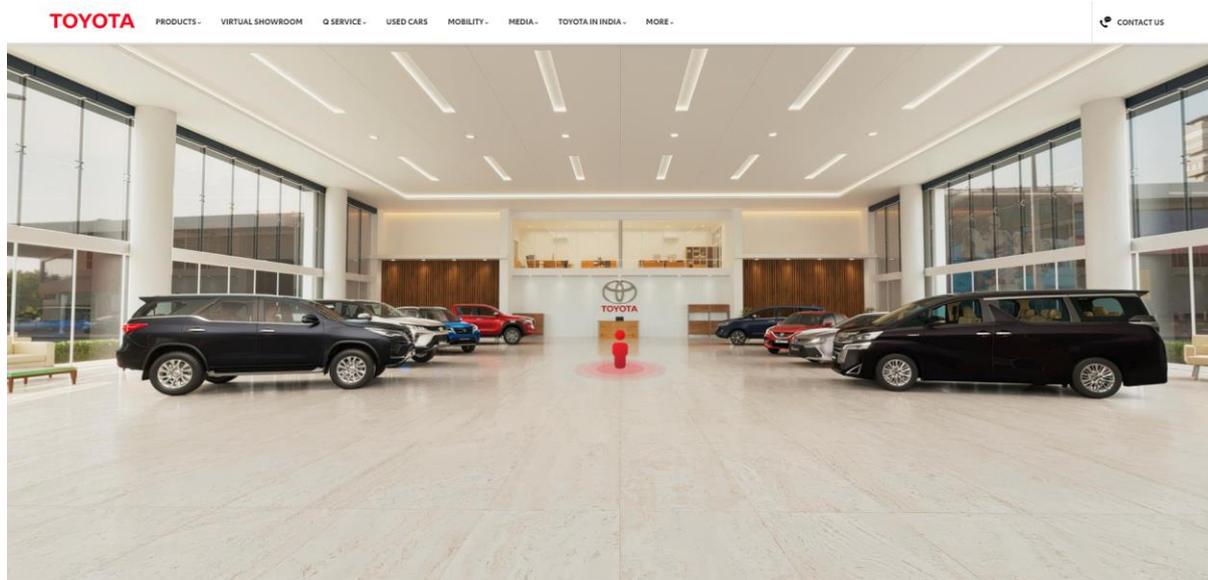


Figure 12: Toyota Virtual Showroom screenshot

Geberit Virtual Showroom is advertising a selection of plumbing and bathroom products produced by Geberit ([Geberit, n.d.](#)). This example adapts the qualities of a classic exhibition environment, presenting the user with a room broken up into numerous different booths with different selections of products on display (Figure 13). This virtual showroom combines modern aesthetics with simplicity. Once again, it is not as interesting and memorable as the Vredestein Experience, however, it has a modern feel and distinct colour scheme reflecting Geberit’s branding. Despite being consistent and modern aesthetically, the user will quickly cover all the products as there is little room to explore. This showroom focuses more on the products rather than the experience, which may be the desired effect. Companies want to use these experiences as an online alternative to an exhibition booth or showroom, to inform the viewer about the product without distractions. This virtual showroom is clear, informative, and guides the user through several different booths advertising different products, providing an effective way to present products.

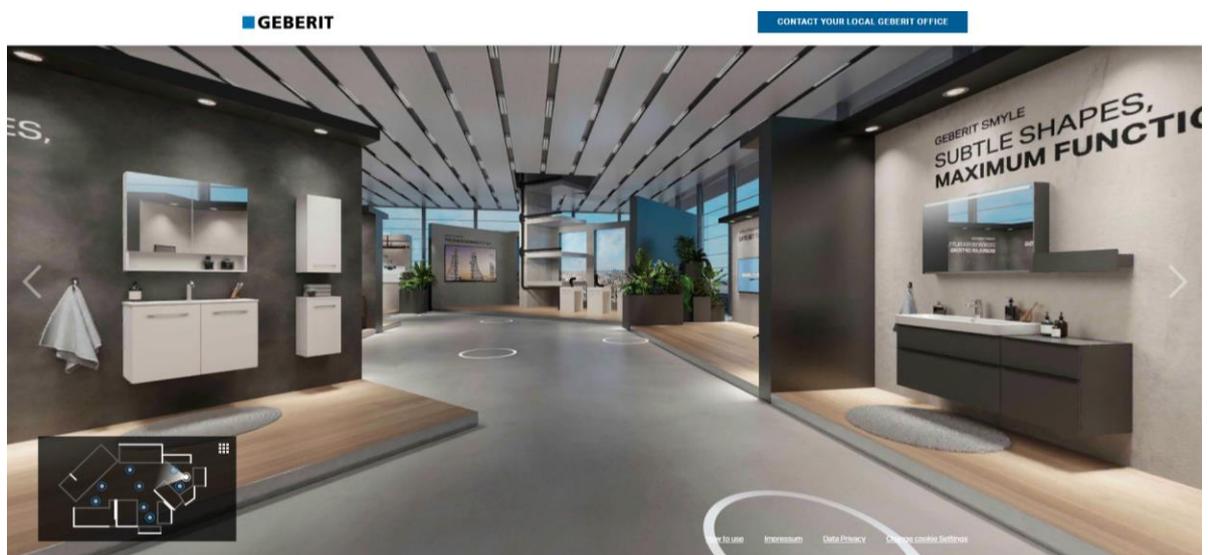


Figure 13: Geberit Virtual Showroom Screenshot

WMF Coffee Machines Virtual Showroom is advertising a selection of coffee machines produced by WMF ([WMF, n.d.](#)). Once again, this scene is small in scale and adopts a classic showroom aesthetic. As seen in Figure 14, the branding of WMF is portrayed and the attention of the viewer is focused on the machines and the information about them.

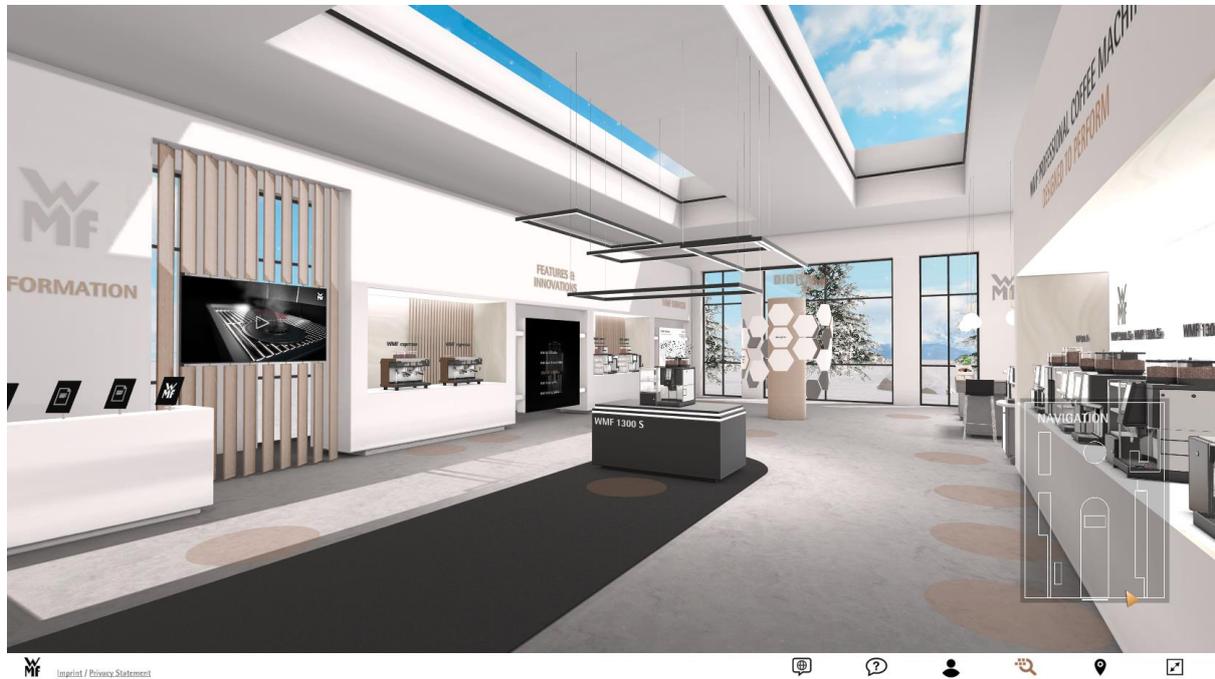


Figure 14: WMF Virtual Showroom Screenshot

Shaerer Virtual Showroom is advertising a selection of coffee machines produced by Shaerer ([Shaerer, 2021](#)). This experience is very similar to the previous example, presenting a classic showroom aesthetic, this time reflecting the Shaerer branding (Figure 15). It is clear that these two experiences are produced by the same 3D developers, but distinct changes in style and content work to make this less apparent. The goals of these products are clearly to portray the branding of the company and to effectively display their products in a condensed, informative, and overall pleasant experience.

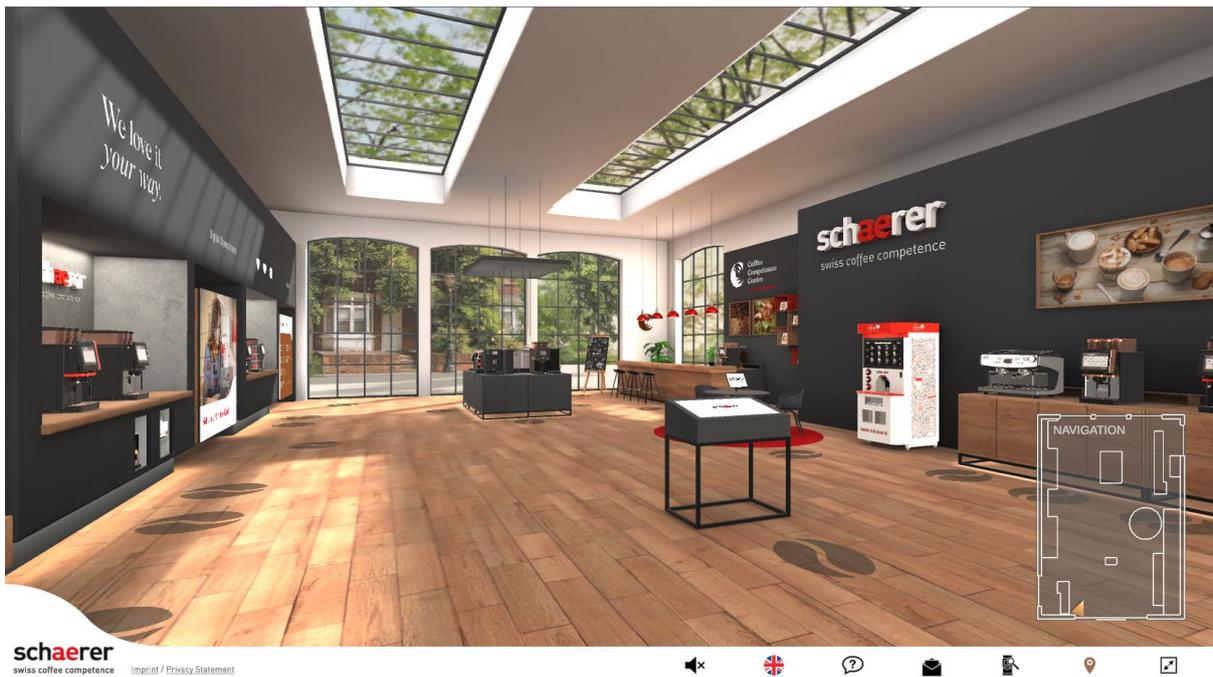


Figure 15: Shaerer Virtual Showroom Screenshot

All the examples analysed have both strengths and weaknesses. The Vredestein experience created a very memorable and interesting experience, however, would have been far more expensive to produce than the other examples. Furthermore, the large scale and extensive detail of the numerous scenes made the experience less focused and despite being memorable, it was easy to get distracted from the products being advertised. The other examples were more focused on the advertisement of the products, with the scenes remaining simple and adopting styles comparable to real-world showrooms. This prevents the user from becoming overwhelmed and reduces the cost of development dramatically. In conclusion, the environments need to support the products and not detract from them, whilst being affordable to build.

Alongside this analysis, a survey was conducted asking people several questions about three of the examples, Vredestein, Geberit, and Schaeferer. The results of this survey reinforced most of the conclusions, with Vredestein generally being the best marketing tool, as well as the most memorable option. The survey showed however that people felt Geberit was the most effective at presenting the products and that the much higher development cost of a complex scene with multiple rooms like the Vredestein was not entirely worth it.

The full results of the survey can be found in [Appendix 4](#) and [Appendix 5](#).

Virtual Showroom Environments Survey - Responses - OliverHarrison444399.xlsx

Virtual Showroom Environments Survey - Graphs - OliverHarrison444399.pdf

In conclusion, it is clear that to create a memorable yet effective and affordable virtual showroom, a balance must be found. To find this balance, the environment will need to be unique, whilst maintaining the feel of a classic showroom experience.

2.4.4 How can procedural modelling be used to reduce the cost of creating virtual showroom environments?

Procedural and manual modelling have many differences, some being strengths and others weaknesses. As discussed in [Section 2.2](#), procedural workflows have been growing in popularity over time and excel in certain applications. To compare both workflows, a SWOT analysis was conducted.

The full contents of the case study can be found in [Appendix 2](#).
Case Study - SWOT analysis of procedural vs manual modelling - OliverHarrison444399.docx

Both modelling methods have both benefits and drawbacks, however, it is clear that manual modelling is better suited to quick assets that will not need to be drastically edited or replicated. The strengths of procedural modelling are clear, it excels when an iterative modelling workflow is required, and as described by R.M. Smelik in his 2014 paper ([Smelik, R.M., 2014](#)), “a simple set of input parameters or a few generation rules of the procedural model yield a wide variety of models.” This makes procedural modelling an ideal method of creating virtual showrooms, or at least a base that can be developed further using manual modelling methods once approved by a client.

One dangerous weakness of procedural modelling is finding a balance between customisation options, and the user experience. If a procedural tool becomes too complex, with too many options, it will be difficult for the user to create assets efficiently. On the other hand, if the tool is not complex enough, with limited customisation options, it may not be possible to create the required asset, making it a worse option than manual modelling. To find a balance between complexity and usability, the interface would need to be easy to understand and use.

Following the first few stages of research, work on a prototype began. This prototype was created based on research of existing products, and tried to implement features that would be key to producing an effective virtual showroom environment. Furthermore, this process acted as a progressive way to investigate and learn how to achieve various results procedurally, using geometry nodes.

After several weeks of research and development, a prototype with enough complexity was ready for the first testing round. This prototype used the standard Blender modifier UI, with all the customisation options compiled into a long list of values under the geometry node modifier. Testing with the 3D team at Letink Design was conducted, as well as a demonstration of the functionalities to the stake holder Dave Letink, to get feedback on the customisation and user experience.

2.4.4.1 Usability test plan

To reliably answer the remaining sub-research questions, testing of a prototype was required. To ensure that the testing sessions would be effective and provide the necessary information, a usability test plan was created.

The full usability test plan can be found in [Appendix 3](#).
Graduation usability test plan - OliverHarrison444399.docx

Using the usability test plan, it was possible to organise effective testing sessions and formulate surveys that would provide the relevant information to answering the remaining sub-questions and increasing the success of the procedural tool.

This testing plan was used to set up a testing session, where the 3D team at Letink Design were tasked with using the tool to create a virtual showroom of their liking, as well as being asked some small feedback points provided to imitate a client. Following this, they were asked to fill in a survey about their experience with the UI and customisation options.

The full results of List UI testing can be seen in [Appendix 6](#).
Prototype v1 testing - OliverHarrison444399.pdf

The results of the survey showed that 3D modellers would choose to use the tool to create a virtual showroom, before using manual modelling techniques to add finishing touches that required more control.

Despite this positivity and eagerness to use the tool, it was clear that it could be confusing and difficult to use efficiently. This difficulty was seen particularly in 3D modellers who do not frequently use Blender, which includes almost half of the 3D team at Letink Design. This issue was emphasised by the part of the test where the modellers were asked to make specific changes to their showroom. Due to the customisation options being in the form of a long list, as shown in Figure 16, users struggled to find the correct input to alter. To make the tool easier and more desirable to use, a different approach would need to be taken to organise the customisation options. Furthermore, a user manual could be developed to guide the user, explaining how to use the tool and directing them using colour coordination and labelling within the node editor.

Blender geometry nodes currently have limited functionalities for organising parameters, and it is not possible to create tabs or groups to break up the list seen in the modifier tab. It is however possible to create groups, frames and labels within the node editor, all of which can be coloured. These functionalities could be used to create a user interface that would be more clear and easy to navigate.

Alongside further development of the tool according to feedback, the tool was organised into three different UI/navigation options, so that they could be compared in the second testing round. The first option was same Blender modifier list UI as seen in Figure 16. However this time due to the increasing complexity of the project and more available parameters, the list was longer and even more difficult to navigate efficiently. Secondly, using the customisable Blender UI, it was possible to layout the different node groups in multiple different viewports, as shown in Figure 17. The custom cluster UI option takes a lot more space than the default UI, however, it allows for colour guidance and a more clear grouping of different parameters. The third and final option was manual navigation of the geometry node tree, as shown in Figure 18. This would give users a less cluttered view, as well as allowing a better understanding of how the tool works, however, would have a much steeper learning curve.

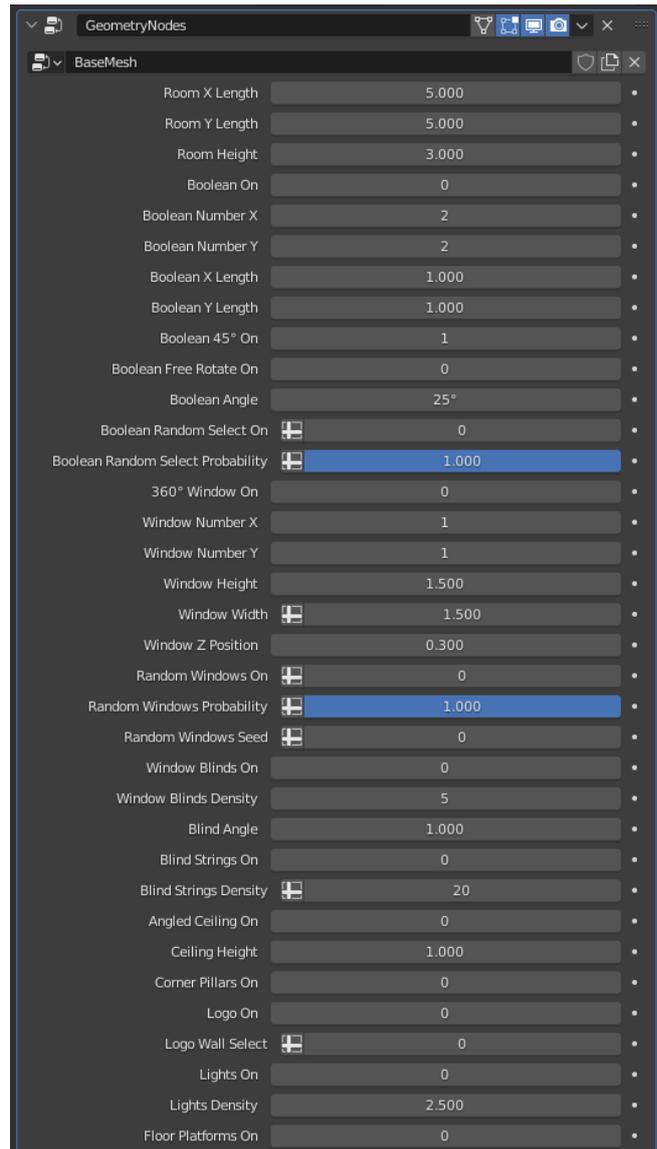


Figure 16: Geometry node modifier UI

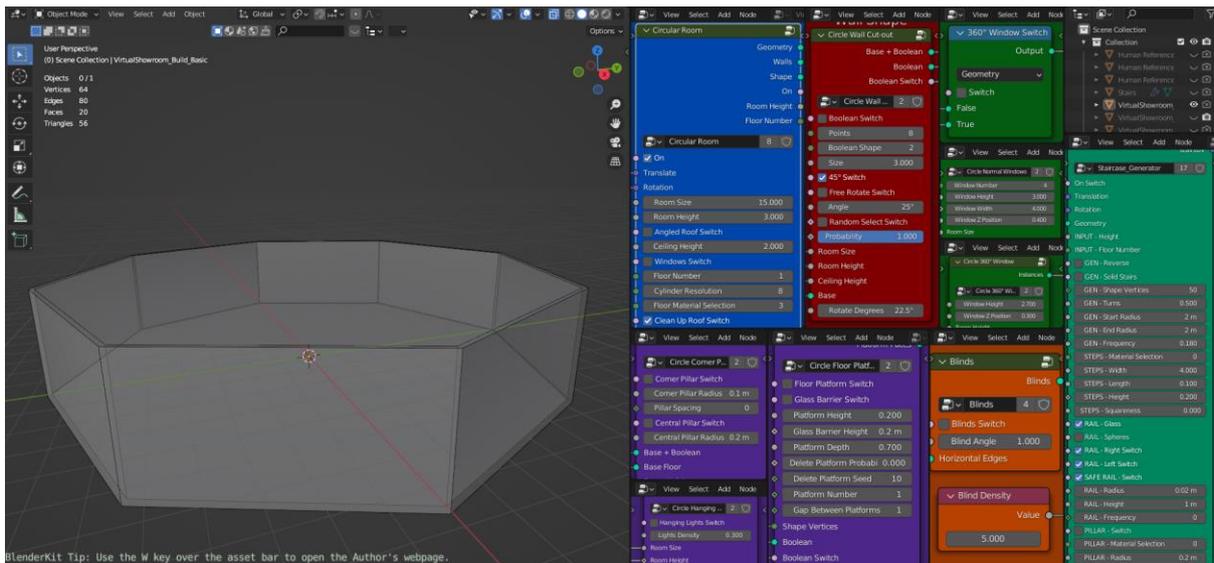


Figure 17: custom cluster UI

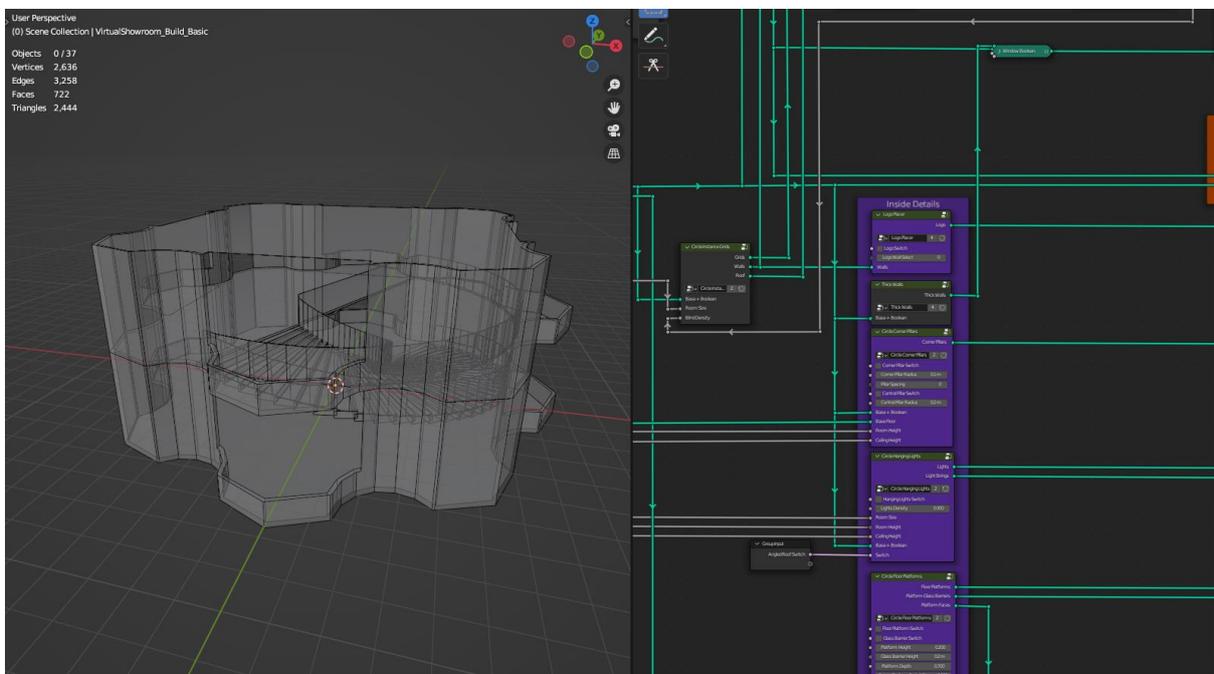


Figure 18: Manual navigation

With additions, improvements, and the implementation of the three navigation options in place, a second testing round was conducted. The second testing round also included an updated and improved survey, so that relevant information about the different navigation options could be collected, as well as allowing for the collection of both quantitative and qualitative data. This would be an improvement from the first testing round, which focused almost entirely on qualitative results.

The full results of multiple UI options testing can be seen in [Appendix 7](#) and [Appendix 8](#).
 Prototype v2 testing - Individual answers - [OliverHarrison444399.pdf](#)
 Prototype v2 testing - Graphs - [OliverHarrison444399.pdf](#)

The results of the testing clarified several points. Firstly, the test results once again showed that 3D modellers felt they would save time and money using the procedural workflow and would choose to use the tool over manual modelling, at least for a base that could be refined manually. Secondly, it was clear that the preferred navigation method was the manual option. Despite being more difficult to learn to use, it was preferred by the 3D team at Letink due to the lack of clutter and the ability to follow the flow of the nodes and partially understand how some elements would affect others. Thirdly it was clear that the customisation options at this stage were satisfactory, with some small elements that could be reworked or added during the polishing stage of the project. Finally, the user manual was a partial success, helping to guide the users in using the tool. It was clear however that this is one of the main elements that needed improvement.

Through the multiple testing sessions and the SWOT analysis of procedural modelling compared to manual modelling, it is clear that the procedural tool will be a valuable asset for the 3D team at Letink Design. The tool is able to help to efficiently create high quality virtual showroom environments of varying complexities, and despite requiring time to learn to use effectively, will significantly improve the process as well as acting as an impressive marketing tool.

2.4.4.2 Tool documentation

Based on the results of testing rounds, it was clear that the tool needed a user manual to guide the users. Despite the implementation of colour coordination in the node tree UI version, users struggled to keep track of what each colour meant. Furthermore, the large number of customisation options spread out across the screen made it difficult for users to know where to start and even led to them missing several key functionalities.

The user manual would be an interactive document, with clear naming, with the same colour coordination as the tool itself. This tool would act to explain each functionality in more detail than was possible in the Blender interfaces, as well as laying out the optimal order for building a virtual showroom using the tool. A week was spent structuring all of the relevant information into an interactive PDF document.

The full User Guide document can be found in [Appendix 9](#).
Virtual Showroom Generator - User Manual – OliverHarrison444399.pdf

2.4.5 What elements of the virtual showroom need to be customisable and to what extent?

Customisation is one of the key benefits provided by procedural tools. Allowing the user to quickly shape an asset to their needs or the needs of their client is a primary factor in what makes procedural tools worth the time required to set them up. In the case of a virtual showroom, there are countless options for customisation. To maintain the benefit of efficiency provided by a procedural tool, a balance must be found between extensive customisation options and a manageable workflow. The point of creating a procedural tool is

that it is possible to quickly create assets, as well as being able to return and iteratively edit them. If the tool becomes too complex, allowing for the user to control every detail, it will likely be more difficult to use than manual modelling methods.

Following the analysis of existing showrooms in [Section 2.4.2](#) and considering the skills that had been developed with geometry nodes so far, it was possible to create an initial plan for the form the showroom would take and the elements it would include. Several important factors were considered during this. Firstly, research made it clear that a classic showroom feel was most desirable for a virtual showroom environment, even if a more impressive environment could be more memorable. To achieve this, initial development would be focused on one room with platforms that could be used to display products. As well as this, uniqueness would be an important factor for marketing and selling the virtual showroom product. This is something that several of the showrooms that were analysed lacked. To achieve this, the room would include as many customisation parameters as would be possible without the tool becoming too complex to use. This balance would be a key result of iterative testing and prototyping throughout the development phase.

To refine the selection of customisation options, questions exploring the available options were included in the testing rounds. The 3D team at Letink Design provided feedback on the level of customisation that was possible and what options they felt were missing.

The full results of both testing rounds can be seen in [Appendix 6](#), [Appendix 7](#) and [Appendix 8](#).

Prototype v1 testing - OliverHarrison444399.pdf

Prototype v2 testing - Individual answers - OliverHarrison444399.pdf

Prototype v2 testing - Graphs - OliverHarrison444399.pdf

As well as discovering features to add, the testing rounds highlighted certain customisation features that were not necessary and added complexity to the tool but ultimately did not enhance the results of the virtual showroom environments produced. These results were a key element of the testing conducted, as users who did not understand the inner workings of the tool were confused by certain controls and the results they created. From this, it was possible to simplify several features, alongside adding more that were missing.

Using the results of the testing with the modelling team, and the multiple progress meetings held between myself and Dave Letink, a list of possible elements to implement was produced. The feedback rounds provided important information about the importance of each feature. Using HacknPlan, an online service for planning game development projects, it was possible to organise these features by importance. This workflow was important for keeping track of progress, and ensuring that the most important features would be implemented first. In addition, this allowed for the allocation of time to structuring and organisation of the node tree, so that the result would be easy to navigate and understand.

3. Development

3.1 Learning

Lack of prior experience with procedural modelling and geometry nodes meant that this project was a large learning experience. The initial stages of the project involved following many tutorials to learn to use the different nodes available, in different ways.

After developing a basic skill using procedural node-based workflows, it was possible to create the proofs of concept used in [Section 2.4.1](#) comparing Blender geometry nodes and Houdini. Geometry nodes were chosen as the platform for creating the tool, and further practice was conducted by following tutorials and researching different techniques. The large popularity of Blender made it quite easy to find quality resources for learning and developing skills of varying complexity, despite how new geometry nodes are.

During the research, an impressive project ([sozap, 2022](#)) by Sozap, a 3D generalist on the Blender Artists forum was discovered. This project pushes the limits of what is possible using geometry nodes and an important learning experience during this project consisted of recreating large portions of it personally. This process helped significantly with developing the necessary skills for this project. Furthermore, despite his project not being a part of a tutorial, Sozap was very helpful and open to answering questions. By following the thread and asking questions myself, it was possible to progress quite far with replicating the project. At a certain point in development, enough new skills and knowledge had been developed to begin creating the procedural virtual showroom tool.

As well as the insights in the thread detailing how he achieved various parts of his Abandoned House project, I contacted Sozap privately with various specific questions about his project, as well as my own. Throughout development, discussions with Sozap provided important learning points for achieving some of the more complex functionalities of the tool.

3.2 Production

Once design choices were made, and enough understanding of geometry nodes had been developed, work began on creating the prototype. This prototype consisted of one room that could be customised in a multitude of ways, as well as basic functionalities for adding lights, floor platforms, window blinds and other decorations. This version had all of the customisation values directed to the modifier tab and was used in the first testing session.

Following feedback on the prototype, several steps needed to be taken to continue the development and add complexity. Firstly, the node tree was reorganised into groups that could easily be reused later in the process, as well as allowing the node tree to be cleaned up dramatically as seen in the comparison between Figure 19 and Figure 20.

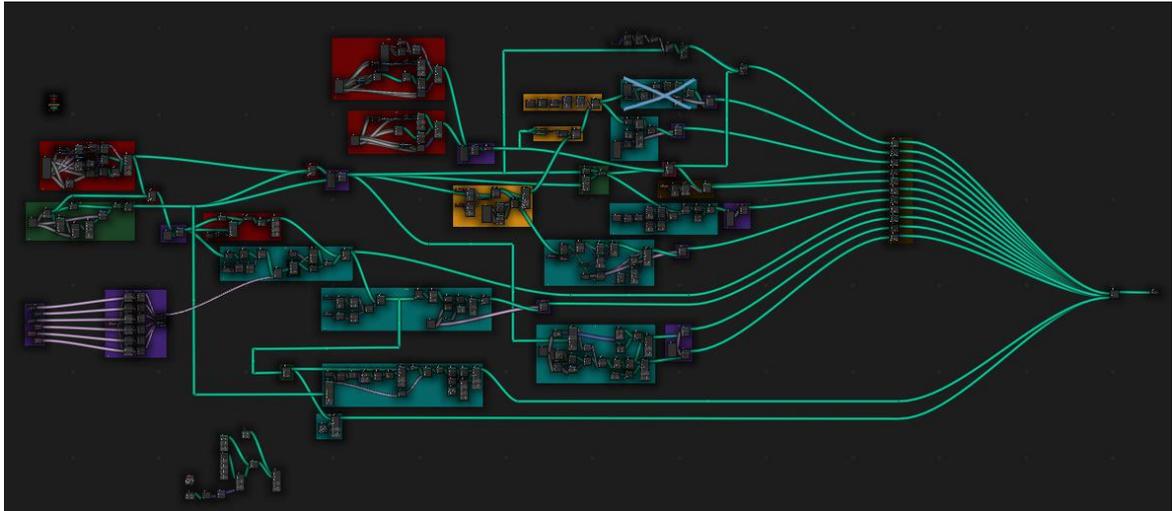


Figure 19: Node tree before reorganisation

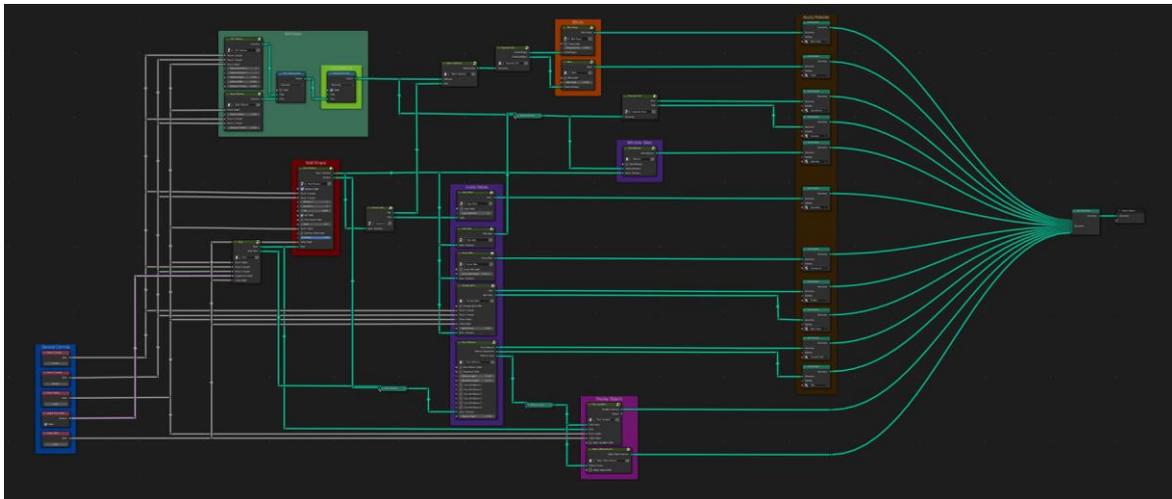


Figure 20: Node tree after reorganisation

Following this reorganisation, it was possible to begin adding more complex functionalities. The new customisation options were chosen from the results of the first testing session in [Section 2.4.4](#), as well as feedback from Dave Letink and the results of research in [Section 2.4.2](#).

The new functionalities added at this point consisted of small elements like ceiling supports, ways to add objects to platforms, spotlights, and various bug fixes. When adding new elements, it would often take time to ensure that they worked properly with all of the pre-existing elements. Alongside these small features, the option to have additional rooms and the option to choose between a rectangular or circular base shape was implemented. This required another level to be added to the grouping, containing the entire room generation tree into a group and joining a total of 5 of them with connecting tunnels, each of which could be toggled on or off (Figure 21). This made the tool able to create far more interesting and expansive interior environments but the increasing complexity of the setup meant that implementing new features was becoming increasingly difficult and time-consuming.

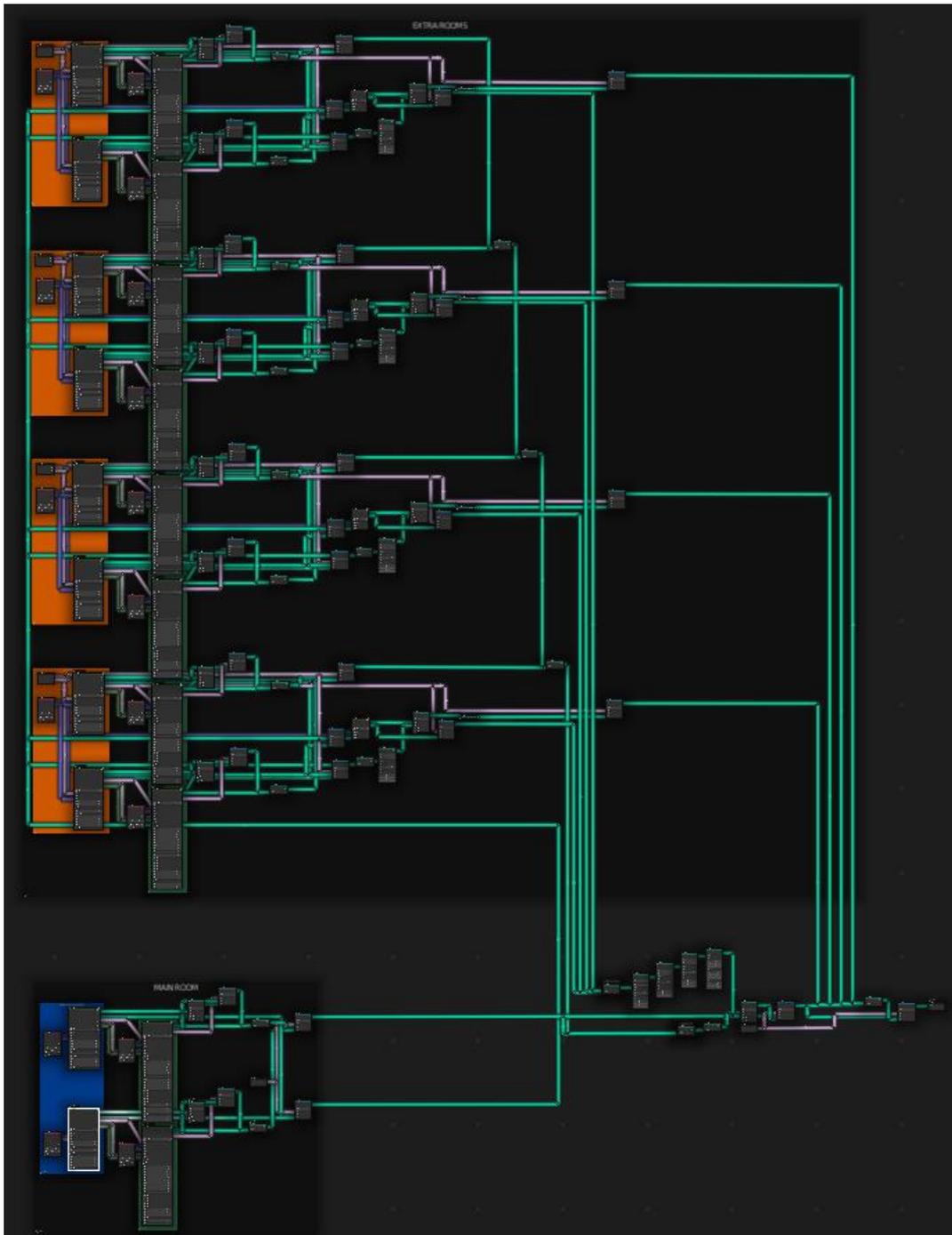


Figure 21: Base level of node tree (Adding Complexity)

At this stage, the node tree was well organised and this would be maintained during further development. However, with the modifier controls removed, all of the customisation parameters were within the node tree, which would likely cause difficulties for users attempting to use the tool. Before arranging a second testing session for the updated tool, options for navigating and controlling the tool were to be set up so that they could be compared.

Following the second testing session, functionalities were added, removed, or refined according to the feedback received. As well as this, time was spent to check that everything worked correctly and fix any issues that had previously been overlooked or had been caused by new features interfering with older elements.

Alongside development, a user manual was being made and underwent significant improvements following the second testing session. With the changes in place, it was expanded to cover the entire tool, including the multiple room options, shapes and every available feature within the tool.

In addition to the main procedural tool, several smaller scale tools were created both to provide extra visual elements to fill the rooms, as well as providing more control for some elements like the floor platforms. These elements applied the skills that had been learnt throughout the project to smaller scale node setups. These elements are showcased in a post made on blenderartists.org: <https://blenderartists.org/t/procedural-interior-assets/1379891>.

The project was nearing the planned deadline, so it was time to stop implementing new features and to focus work on the presentation of the tool, as well as creating renders and animations to showcase the possibilities of the tool. To show off the tool and receive some online feedback, a post was made on blenderartists.org to share the result with the community that provided a lot of guidance and advice on complex uses of geometry nodes throughout development ([Blender Artists, 2022](#)). The post was featured on the weekly Blender Nation best of Blender artists post ([Blender Nation, 2022](#)), and because of it, an invite was received to showcase the product and process at the Girona film festival in October 2022, as a part of video conferences demonstrating the possibilities of Blender. (Figure 22) This invitation was an unexpected and exciting result of the project, showing the tool as an exciting innovation in Blender geometry nodes, which is quickly becoming a popular and powerful tool for the procedural modelling community.

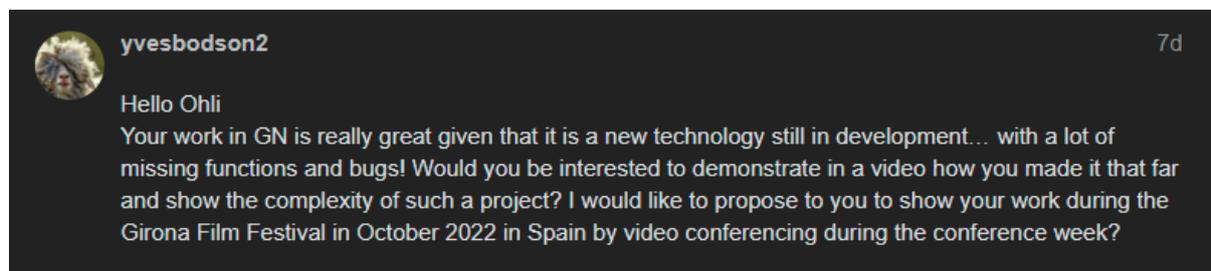


Figure 22: Invite to the Girona Film Festival 2022

4. Final Product

The goal of this geometry nodes tool is to be an easy and efficient way to create detailed concepts or bases for virtual showroom environments.

To achieve this, the geometry node setup creates rooms entirely procedurally through the use of available nodes in Blender version 3.1+. The tool consists of multiple layers of node groups due to the scale and complexity of the project. The base layer connects both room types, the staircase generator and a tunnel generator, allowing for easy toggling between room types, as well as connecting up to 5 rooms via procedurally generated tunnels (Figure 21).

Within this base level, there are 4 main node groups that are used multiple times. Firstly the rectangular room generator, which is made up of multiple smaller node groups for each stage in the construction of the room shape, as well as for additional elements like windows, lights, floor platforms, etc. This grouping system was created so that the tree could be organised more easily, as well as allowing for the reuse of node groups. This was particularly useful when developing the circular room option, which is a similar setup. The groups could be reused with slight reworks to ensure they functioned as intended with the new room shape (Figure 23 & Figure 24).



Figure 23: Rectangular room generator and included node groups



Figure 24: Circular room generator and included node groups

Each room is also connected to a staircase generator, which can be customised extensively as well and automatically adds stairs when floors are added (Figure 25).



Figure 25: Staircase generator

Finally the tunnel generator is used to automatically connect extra rooms to the primary room, creating a tunnel where the rooms are closest to each other and cutting the appropriate holes in the walls (Figure 26).

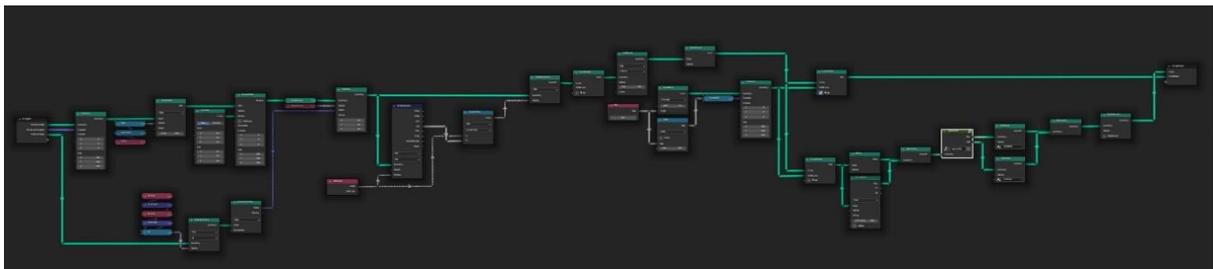


Figure 26: Tunnel generator

The tool has countless customisation options, consisting of 2 different room types, a circular and rectangular setup. These rooms can be attached to additional rooms with tunnels, the rooms can be given additional floors with automatically generated staircases, which can also be customised in many ways. A lot of other elements can be customised such as the shape and size of the rooms, windows, ceiling lights, floor platforms, window blinds etc.

The full list of customisation options along with descriptions of each parameter can be found in the user manual ([Appendix 9: Virtual Showroom Generator - User Manual - OliverHarrison444399.pdf](#)).

The tool can be used to create an endless variety of virtual showroom environments. Some examples of rooms can be seen in Figure 27. Additional links and images for the final product can be found in [Appendix 10](#). A video has also been created to showcase the building process and possibilities of the tool, and can be found at: <https://www.youtube.com/watch?v=LTcu2WzbL78&t=3s>

A post on blenderartists.org were made showcasing the tool and its possibilities, as well as documenting some of the work behind a geometry node project of this scale: <https://blenderartists.org/t/procedural-interior-showroom-with-geometry-nodes/1377390>

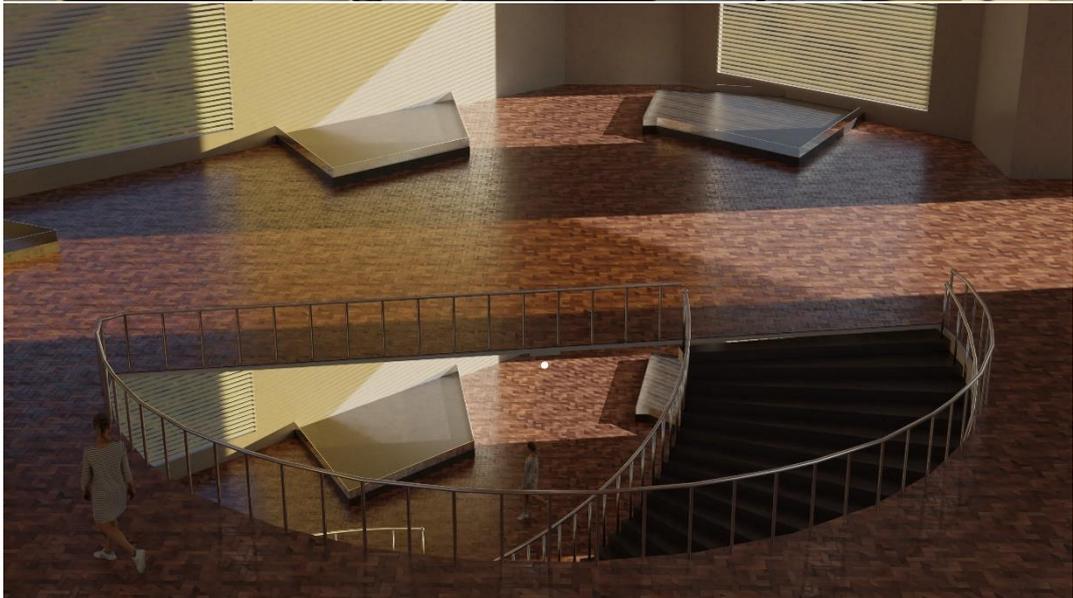


Figure 27: Examples of interiors created using the tool

5. Conclusion

Preliminary research into the workflow for creating virtual showroom environments at Letink Design was done to justify the following problem:

- Manually modelling virtual showroom environments specific to varying client needs is expensive and time-consuming, but the complexity and steep learning curve of procedural modelling techniques make the topic difficult for small companies to research.

To solve the identified problem, research into the subject was done and a solution was defined:

- A node-based procedural tool made in Houdini or Blender to help with creating virtual showroom environments that can be customised to the needs of different clients.

This solution was used to define the main research question:

- How can one develop a node-based procedural tool that can create effective virtual showroom environments, so that Letink Design can save time and money when creating iterations based on the needs of different clients?

To answer the main research question, it was divided into four separate sub-research questions.

The first research question identified which procedural modelling platform would be best suited to the project, as well as investigated and analysed the popularity of the various available platforms. Blender geometry nodes were ultimately chosen, which answers the “How can one develop a node-based procedural tool” part of the main research question.

The second research question explored existing virtual showrooms and identified what elements make them successful. It was concluded that to create a memorable yet effective and affordable virtual showroom, a balance must be found between complexity and functionality. A showroom needs to be unique, whilst maintaining the feel of a classic showroom experience. This answers the “that can create effective virtual showroom environments” part of the main research question.

Sub-research question three explored the benefits of procedural modelling over manual modelling workflows. Testing sessions also revealed that manual navigation of a complex node tree, supported by an extensive colour coded user manual is preferred over the default modifier tab list or the customised interface that was created. This research helped answer the “so that Letink Design can save time and money” part of the main research question.

Lastly, the results of both testing rounds combined with client feedback and research for the second research question guided the development of the tool and the many customisation options that were included. This answered the “when creating iterations based on the needs of different clients” part of the main research question.

Combining the findings of all the sub-research questions into an answer to the main research question results in the following:

- Develop a procedural node-based tool using Blender geometry nodes, that provides the user with an efficient way to create a large variety of effective virtual showroom environments.

This explains the design theory behind the Procedural Interior Showroom Generator made with Blender geometry nodes.

Besides the main functionalities included in this answer, additional elements and knowledge were required to make the tool fully functional. These elements are described in [Section 3](#).

Discussion

The aim of this research was to find how to develop a tool for saving time and money during the production of effective virtual showroom environments, considering the need to create various iterations for different clients. The results of my research indicated that a procedural tool created with Blender geometry nodes would be able to provide a solution. Furthermore, research into existing products and feedback on prototypes provided information on the aesthetics of the showroom and what elements should be customisable. Finally, research and testing showed that manual navigation of the tool, supported by an extensive user manual was the best way of using the tool.

Some of the research results were as expected, with procedural modelling being a way to save time and money when needing multiple iterations. SWOT analysis comparing procedural modelling against a manual workflow combined with survey results clearly showed that the procedural tool was preferred and would save significant time. It was also expected that Blender geometry nodes could be used to create a complex procedural tool for creating virtual showroom environments. Despite this hypothesis, Houdini was a close contender, offering a more developed and extensive set of procedural tools. Ultimately, the data gathered showed that the popularity of Blender, the free nature of the software, and its already existing role within the workflow at Letink Design made it the best platform to use.

Not all the results gathered were expected however, my research found that impressive and complex showroom environments like the Vredestein experience were not as effective marketing tools as smaller scale, more classic showroom environments. The results of in depth analysis combined with qualitative and quantitative data from a survey showed that a balance between an impressive and memorable scene, and a focused and more classic showroom feel would need to be found to create the most effective experience. The survey was completed by a large variation of participants ranging from teenagers to pensioners, including people experienced with navigating 3D environments as well as people without such experience. This spread of participants made the results reliable and without bias.

Furthermore, results from the prototype testing sessions discovered that the preferred navigation method for the tool was manual. This was not expected as the node tree was very complex and it was predicted that the large number of crossing wires and connected nodes would be intimidating for the user, particularly those who were not experienced with Blender. Quantitative results of the testing showed however, that most users preferred the manual navigation option. Users explained that they found the other options too cluttered and despite the higher learning curve of the manual navigation, they enjoyed being able to follow the flow of the nodes to better understand how the tool works and what elements will affect others. Furthermore, the testing participants expressed how after overcoming the initial intimidation from the complex node tree, they realised that the manual navigation was not much different to the cluster interface, with the same controls and colour coordination but a less cluttered viewport.

The iterative prototyping throughout the production phase of the project proved very useful for ensuring that the most important features and customisation options were being implemented. Multiple testing phases at different stages in production defined the plans for expanding and updating the tool. The testing rounds gathered feedback from the 3D team at

Letink Design, the intended users of the tool, and brought to light the features that were missing, the controls that were unclear, and the elements that were not needed. Alongside testing sessions, the product was presented to the marketing team at Letink Design on several occasions to receive feedback on the aesthetics and customisation options. By frequently searching for detailed feedback on the aesthetics, functionalities and navigation of the tool, I was able to fine-tune it to the needs of the user and create a product that Letink Design is satisfied with.

Despite detailed research and varied sources being used to provide the best solution to the problem provided by Letink Design, it was not possible to test the effectiveness of the resulting scenes in virtual showroom applications. Since the full implementation of a virtual showroom environment in an interactive application requires a lot of input from programmers and UI artists, testing to verify the quality and effectiveness of the created environments with possible end-users was not possible. This meant that though the theory behind the aesthetics was well backed up and the feedback from 3D developers trying the tool had been applied, it was not possible to gather data and feedback for how the scenes performed within an interactive application.

Recommendations

The tool is designed for experienced 3D developers, and to be used as both an impressive marketing tool and a base for creating fully functional virtual showroom environments. Despite the tool providing a lot of features for customisation, it is expected that manual tweaking and the addition of models will be done to refine the experience.

One exciting application of the tool is created by the ability it provides to quickly generate quality scenes. During a meeting with a client, a 3D developer could use a description of an envisioned scene to build an environment with the tool and present it as a 3D concept.

If the tool is developed further, there are several main elements that should be considered. Firstly there are many features that run quite slowly, particularly when adding a lot of details or building a large scene. These features, for example the window blinds, would benefit from optimisation, making the tool more efficient and pleasant to use. Furthermore, if the tool is updated with new Blender versions, the general optimisation updates of geometry nodes could benefit the speed of the tool, alongside new nodes possibly providing simplified ways of achieving certain elements.

Though the tool is able to produce high quality virtual showroom environments at a much lower cost than manual modelling, the implementation of these scenes into an interactive application remains an expensive process that requires a lot of programming knowledge and experience in software like Unity or Unreal. If this process or parts of it could be automated, the virtual showroom product could be made even more profitable.

Firstly, a system or pre-defined workflow to transfer the scene from Blender to Unity or Unreal would be very beneficial. At the moment, the showroom would have to be separated into the numerous objects it is made up of, UV mapped, and the materials would need to be baked into textures to be used in Unity or similar software. Secondly, in Unity, the scene

would need to be set up with collisions, and walkable areas. A script or tool could be developed to automate this process. Finally, the application needs to include interactive elements, navigation and UI. To speed up the development of these elements, a template scene could be created to make the process of building the interactivity of the application easy to repeat for different rooms and clients.

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