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Bachelor Degree
Bernoulli Institute, Computing Science
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July 2022– Groningen, the Netherlands

ABSTRACT

Tilt Brush is a VR application initially created by Google that allows users to create sketches and models in a 3D environment. The canvas is the user's play area and through a set range of tools such as the Mirror or the Selection ones, the process becomes much more accessible. However, when it comes to precision and flexibility, it lacks some rather useful features, including basic tools which allow users to draw simple yet perfect shapes or planar surfaces that lead to more detailed projects. Mastering precision is one of the key aspects that makes the process of creation more satisfying, and the easier it is to handle, the better the results and the user experience are. Guidance tools are a set of transparent shapes that can be transformed in various ways, including non-uniformly scaled, and behave as a ruler. The pointer of the brush snaps on the shape's surface and it remains there for the user to draw on its surface until commanded otherwise. These tools are some of the features that help in overcoming some of the precision and flexibility limitations. For example, they make it much easier for the user to draw both simple and complex shapes without imperfections such as curved or inclined lines. As such, I seek to improve the concept of "guidance tools" by increasing their number and variations. With these, the users may benefit from a higher level of freedom and exactness, leading to accurate and more particular designs.

ACKNOWLEDGMENTS

I thank Prof. Dr. Jiří Kosinka and Dr. Cara Tursun for being great examples of what supervisors should be all about. For their implication, advice, consideration, time dedicated to offering the best answers in the shortest amount of time, and also for the opportunity. Then I would like to thank the University of Groningen for helping me overcome the technical difficulties by providing the equipment necessary for me to complete the project and the online access to documents that were required by me to conduct the research behind the project.

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1 INTRODUCTION

Virtual reality (VR) is the concept that fundamentally allows the users to experience computerized simulations through the use of specialized hardware. The two necessary devices are a VR headset, which is used to access the virtual environment, and a pair of haptic controllers, which are used to control and manipulate the simulation (Figure 1.1). Although the term was not defined right away when VR technology was first developed, the concept appeared approximately 50 years ago. Over time, it grew to encompass a wide range of use cases, and its applications can be found in many different subjects, from medical and military training purposes to education and commercial use today. The various branches of VR developed even further and besides engineering fields such as robotics, mechanics, and optics, it made its way into studying and improving human behavior too, such as psychology. Moreover, certain features proved that it could even serve as a treatment methodology for cognitive issues [4, 5]. With VR sets becoming more widely accessible, entertainment became one of the main focus points for the manufacturers, with thousands of software tools being available for this purpose. Among video games or virtual cinemas, different design programs were developed, standing out due to the new perspective they brought forth.

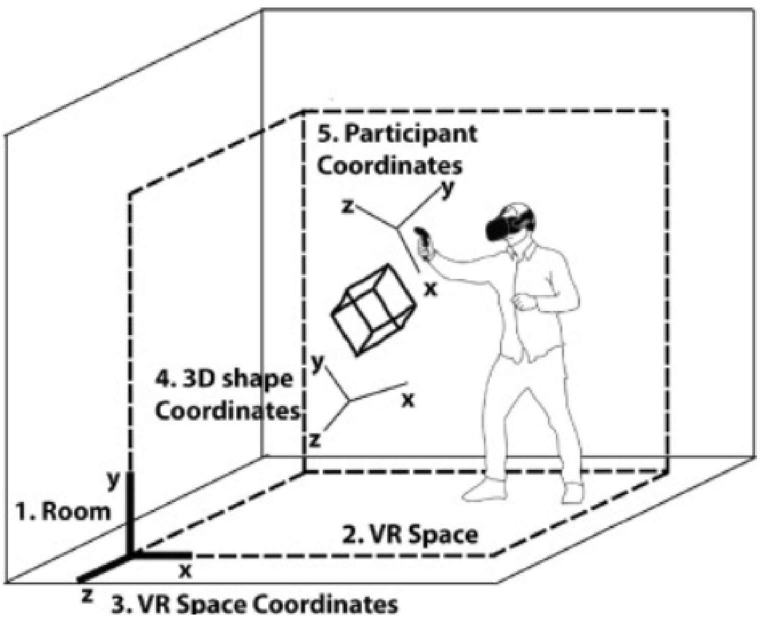


Figure 1.1: A sketch of the fundamental elements of 3D modeling in virtual reality. Image reproduced from [1].

Taking the great expansion and the impact VR has over many fields into account, I decided to take an active step and approach the topic of 3D modeling and sketching. Some of the features that should be treated with utmost importance in this subject are precision and flexibility. At least in the case of Tilt Brush, every slight movement of the user's hand results in a change in how the brush strokes look like. This happens due to the difference in the user's perspective as the whole play area becomes the canvas. That being said, trying to achieve perfect shapes or any sort of stroke that is not irregular is an unrealistic goal without using any of the helper tools, such as the guidance tools. However, default tools and shape variants, such as a plain cube or sphere in the case of these stencils, become obsolete quickly. There is only so much one can achieve without more options, and this is where flexibility comes in. This would allow the transformation of the default tools to make them more viable for additional use cases. In order to enhance both the design process and user experience, proper tools, alongside a high degree of freedom in choice, would reduce frustration and encourage creativity (as I expand upon in Section 2).

Tilt Brush is a VR design software first created by Google and later published as open source. It is the focus of this thesis, and I will be using it to outline the problem and provide a solution. The main goal of Tilt Brush is to allow the users to put their creations in a new 3D perspective, through the use of brushes and modeling tools. The way it works is rather simple. The user needs to connect their headset to the computer and boot up the program, and shortly after, they are spawned within an empty environment that serves as the starting point. Their right hand is always the brush, while their left hand is the tools bar, where they can change colors, brushes, or tweak the canvas with new scenes and lights (Figure 1.2). After researching what the application has to offer and how it is commonly used, I noticed the potential of what Tilt Brush calls a guidance tool, or simply a stencil. I chose to further investigate and I found out that many of the reported shortcomings of the software revolve around precision. This is because, in VR, it can become significantly difficult to sketch and model freely, without using any helper tools, solely due to the 3D perspective and the lack of plane surfaces. Since the core functionality of the guidance tools is to make precision a better aspect, I decided to approach the problem of accuracy and flexibility through stencils. Tilt Brush currently offers only four stencil shapes, but I believe that increasing their number may be a step forward in enhancing the desired aspects.

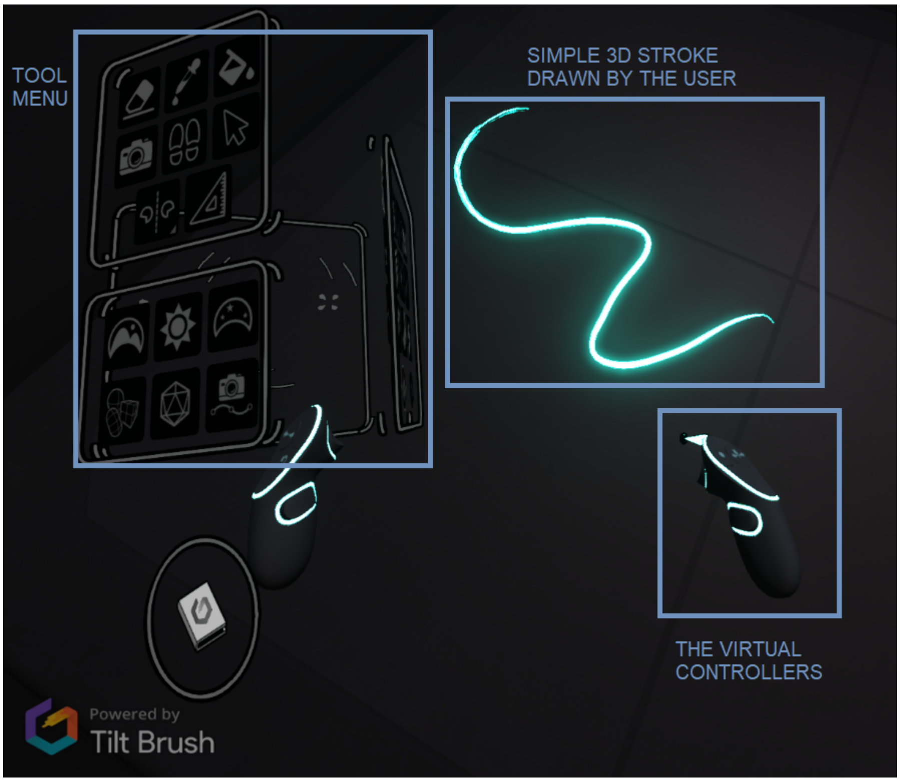


Figure 1.2: Tilt Brush's user interface.

This thesis is divided into 6 sections. Following the first one, which is the introduction itself, comes Section 2 where I talk about related work and the research conducted that helped me identify which way to go next. Section 3 is the concept, where I explain in detail what the stencils are, how they work, and how the proposed solution is the answer to this thesis's research question. Then, in Section 4 I describe the realization process and the steps I took to reach the actual solution and bring it to life. In Section 5, I present the evaluation process of the new features, alongside the results received. Finally, in Section 6, I conclude the thesis and offer a preview of what could possibly serve as future work on the topic at hand.

2 RELATED WORK

Tilt Brush, originally developed by Google, provides a virtual 3D environment designed for users' creativity, allowing them to put their work in a unique perspective. On a whole new level, they can use different art-designated tools to make the best out of their ideas, such as a great range of brushes, sculpting tools, or stencils [6]. The potential behind virtual reality applications such as Tilt Brush was noticed and so it served users on a variety of fronts. Besides the documented beneficial effects on the individual, for example, treatment-wise [6], it was also used as means of education. On top of that, it serves as a useful training ground for different positions in the topic, including designers, painters, and animators. Effectively, Tilt Brush was made in its entirety open to the public, by becoming an open-source product [6, 9].

For an application such as this, the 3D modeling and sketching aspect stands as a prime feature. As an overall effort was put into providing the best experience on this, it allowed Tilt Brush to become more than just a tool dedicated to a specific user base.

2.1 OPEN BRUSH

After the development of Tilt Brush halted and it became open source, a fork was created, starting from the same code base. Since then, it has been constantly updated with additional features. Among others, I found out that the team behind Open Brush actively works on a newly updated set of guidance tools. While the idea is similar, the approach is different. Their solution involves another tool that generates shapes on account of different mathematical formulas. The user starts from a simple shape, and using a vast control panel, they can modify how the shape looks. Eventually, the user can press a dedicated button which transforms the shape into a stencil. However, the feature is not yet complete. Even if it does provide more custom shapes, they cannot be transformed as freely, and more complicated shapes currently lack the precision needed. My solution provides a smaller set of shapes, with 7 stencils in total. They are pre-defined, and all the user has to do is spawn them from their menu. Then, they can easily transform them and start drawing. All 7 shapes are individually coded, providing more specific features for each and with great precision.

2.2 LANDSCAPE ARCHITECTURE DESIGN WITH TILT BRUSH

One example of additional practices can be found if we look at landscape architecture design [2]. Simply put, this is the practice of planning, managing, and designing environments, especially natural ones. Tests and experiments for combining this subject with VR were conducted. Students were provided the chance to use a range of applications, among which Tilt Brush, for the actual architectural design part of the experiment (as seen in Figure 2.1). These would allow researchers to see if it would really fit the field's use cases, as well as if the benefits would be significant, boosting productivity. Also, to check if the new 3D perspective would improve precision, accounting for orientation in space. After the experiments were done, results showed that while inside the virtual environment, the software was fairly easy to use, proving to also be stress-relieving. Students shared that the usage of VR was intuitive and the tools available were accessible. However, some difficulties were encountered when leaning towards more advanced techniques. For example, the surveyed users noted that Tilt Brush was a good choice for simple and basic actions, but when it came down to more, it was seen as limited. The lack of additional precision features made some practices, such as editing or adding more details to projects, difficult or inconvenient [2].

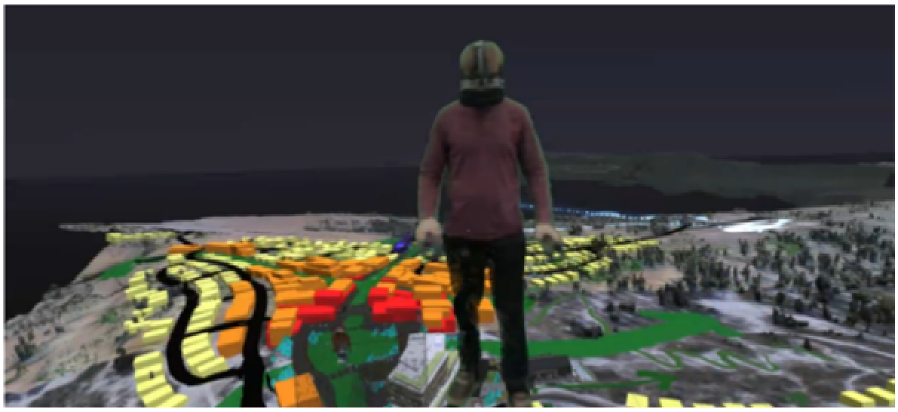


Figure 2.1: Student using Tilt Brush for landscape design and architecture. Image reproduced from [2].

2.3 A VR POTTERY SYSTEM

Another application of VR was recently implemented in a virtual pottery system. This software, called RealPot, involves a mesh generator that creates what the users see as the raw material, and the interactive mesh editor which represents the tools at hand for users to modify the material. These aspects added to an experience similar to reality, due to how natural the material could be manipulated. This was something heavily reliant on the haptic controllers, and participants in the experiment were led through a number of steps that allowed them to experience the said process of pottery. The end discussion and the results of the experiment emphasized the importance of fidelity, familiarity, and how much impact accurate controls have. This does not imply just well-functioning hardware but also the realistic behavior of the controller and the virtual tools available. More specifically, making sure that the virtual instruments are behaving as expected, truthfully adhering to real-life. The more intuitive and easy to use the features are, the better the final projects [10]. As these arguments hold for all applications, I turned to Tilt Brush. The users' freedom and flexibility resides in the application's approach to providing ways of going beyond simple drawings. Among others, these aspects can again be improved through stencils. They enhance the process the better they are, leading to solid results and much more enjoyable processes.

2.4 RECURRING REPORTED INCONVENIENCES

To make the best out of the application's features and reach advanced results, the tools are not the only thing to be considered. The process is equally important, as that is what determines and encourages the user to more ambitious ideas. Tilt Brush itself was also utilized in several therapeutic experiments, and it was found that the provided environment has a great effect on the users' general state of mind, seen as a means of relaxation and an overall calming experience [6]. This can reportedly be achieved and maintained through the ease of use and the reliability of available functions. The features it provided were good enough, as the subjects enjoyed the application and it fitted their needs well. They were ultimately satisfied, even if there is still room for improvements regarding the limitations imposed by the lack of more flexible tools [2, 3, 10]. This leads us to notice a recurring pattern in reported problems. Tilt Brush does not perform too well when it comes to extensive use cases. Simple shapes sometimes prove to be a challenge, making complex ones an even greater one. Details are difficult to add and advanced projects (as in Section 2.1) are even tougher to achieve. Additional options to improve freedom are scarce or missing. Other applications, such as LifeBrush, were as well subject to survey. The feedback received was similar to Tilt Brush's, but the other software was not as user-friendly [7]. This leads to Tilt Brush standing as a solid and generally available choice for 3D modeling and sketching in VR for common users. However, with the goal of improving precision and flexibility, implementing a series of better guidance tools may increase the level of intuition and could make it a more appealing choice for experienced users additionally.

2.5 SOURCES

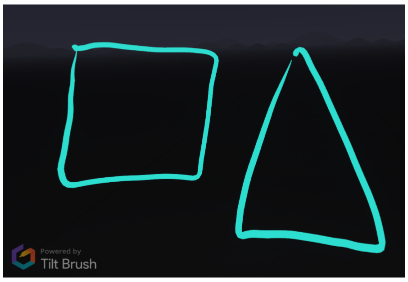
To substantiate my proposal, SmartCat, Scopus, and Web of Science were used to find relevant papers. Most of them were found through the use of various keywords, such as: "Virtual Reality", "3D user interfaces", "3D modeling", "Tilt Brush", "3D sketching", "VR origin", and "VR survey". Other pieces of information were found amongst the papers, articles and books cited.

3 CONCEPT

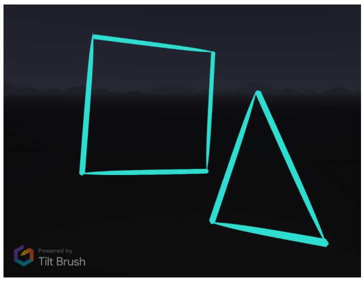
Taking the previous discoveries about the reported shortcomings related to Tilt Brush, and VR in general, I decided to further investigate and research this problem of precision and flexibility. As discussed in Sections 2.2 – 2.4 these aspects strongly affect the quality of both the application and the experience it provides. I believe that addressing these weaker points might remove some of the existing limitations to a certain degree. Therefore, I decided to formulate the following research question: "How can we facilitate Tilt Brush users in overcoming precision and flexibility limitations throughout the guidance tools?".

3.1 LIFE WITHOUT STENCILS

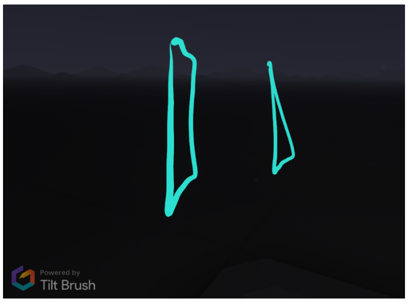
I consider that the answer to the question relies on bringing forth new stencils. It can be fairly difficult to create sketches freely in Tilt Brush without the use of any specific tool. For example, the "Straight Edge" tool turns any brush stroke into a straight line. But when it comes to drawing basic 2D shapes such as a square or a triangle, the users encounter difficulties. Even using the "Straight Edge", it still is difficult to align and properly position the lines to create a simple shape. I have drawn a square and a triangle to show the problems (Figure 3.1). The first set of shapes (both 3.1 - a and 3.1 - c) was drawn freely, while the next set (both 3.1 - b and 3.1 - d) was drawn using the application's ruler. As it can be seen, drawing freely makes it almost impossible to get perfect shapes. The lines are not straight, almost always ending up curved, and they do not always intersect. This is one of the challenges the 3D perspective brings forth. In comparison, the lines of the other set look much better as they are straight, but they still do not intersect completely. Also, line inclination plays an important role when trying to achieve accurate shapes. This merely scratches the surface, as these were two 2D shapes. In a 3D environment, users usually go for 3D shapes too, which are even more difficult to approach.



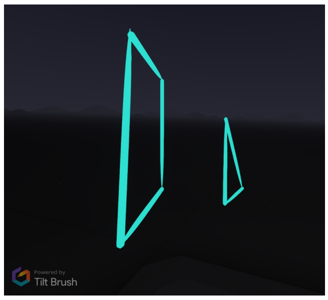
(a) A square and a triangle drawn freely, front view.



(b) A square and a triangle drawn with the tool for straight lines, front view.



(c) A square and a triangle drawn freely, side view.



(d) A square and a triangle drawn with the tool for straight lines, side view.

Figure 3.1: A set of two shapes drawn freely (a, c) and with the helper tool for straight lines (b, d).

3.2 STENCILS IN ACTION

This is where the guidance tools come in. Their purpose is to help the user draw a range of shapes in 3D (or even 2D) with maximum accuracy. They again act as a ruler for shapes, such as a template, but provide much more flexibility. On top of that, these tools are not static. They can be picked up, resized, and even scaled uniformly or non-uniformly, depending on the shape itself. With all these properties combined, it becomes much easier for users to go for more ambitious projects, while experiencing much less frustration. More specifically, ambitious projects involve users creating advanced models by using many primitive geometric shapes, modifying and combining them with one another, alongside many, carefully placed brush strokes. Further touches also become available, increasing the refinement degree of the aforementioned possible projects. Tilt Brush originally offered four stencils: a cube, an ellipse, a sphere, and a capsule (Figure 3.2). They can all be modified by the user to fit their needs. While a triangle cannot be drawn better using the existing guidance tools, I would like to revisit the square example. Below, a square using the cube stencil can be seen (Figure 3.3). The lines are perfectly aligned and their ends meet just right. However, such a guide allows the user to draw a proper cube too, and if the cube is further scaled, more shapes such as a rectangular prism can be obtained (Figure 3.3). The other shapes are just as useful and they open the doors to even more possibilities. What makes the stencils even better, is the fact that they not only allow for drawing on their edges, in the cube case for example, but also on the surface defined by the edges. Every shape can have the whole surface covered, leading to filled shapes too (Figure 3.4). Considering all these features, I have drawn two sketches using the existing guides (Figure 3.5). Take into account that almost all details, such as the hemispheric shape of the cactus flower or the shape of the pills, would have been almost impossible to draw otherwise, and the process would not have been as simple and fast.

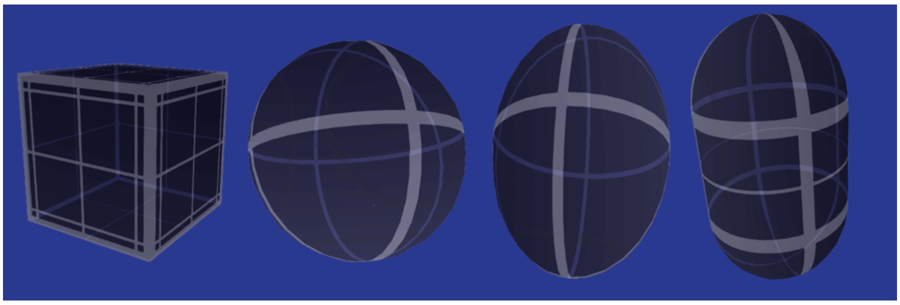


Figure 3.2: The four original guidance tools offered by Tilt Brush.

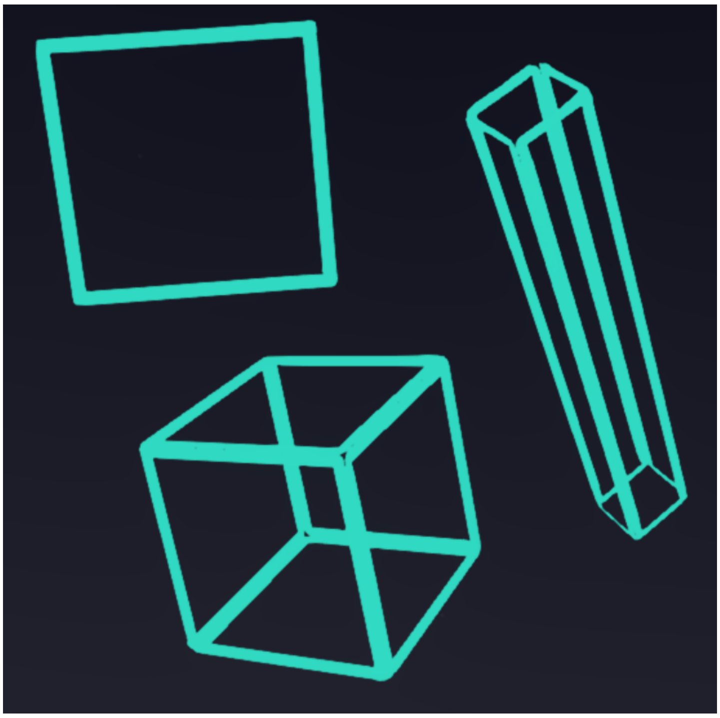


Figure 3.3: A square, a cube and a rectangular prism drawn using the same cube stencil.

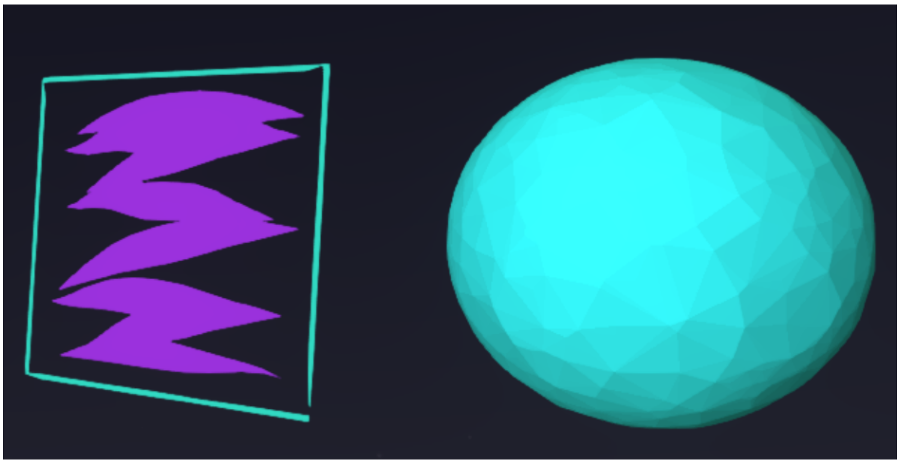


Figure 3.4: A square with drawn face and a filled sphere, done with their specific stencils.

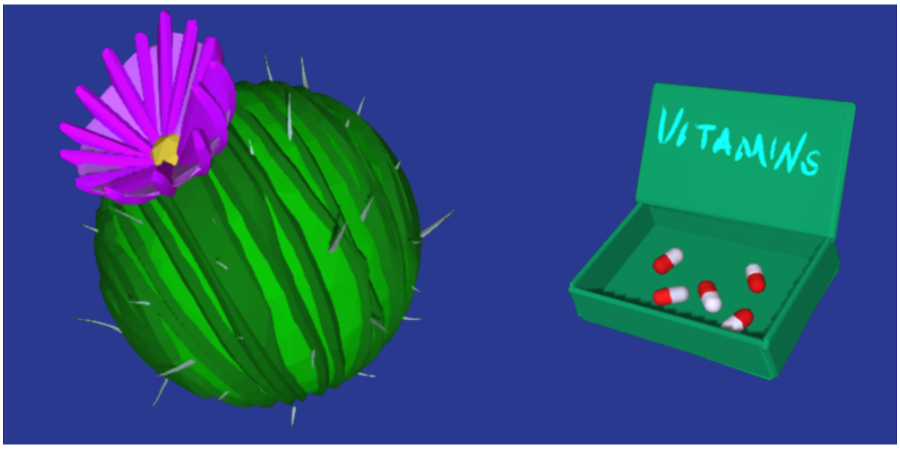


Figure 3.5: A cactus drawn using only the sphere stencil, and a vitamin box drawn using the capsule and the cube stencils. Note the shapes' details, including the petals and the writing on the box.

3.3 THE SHORTCOMINGS

However, sometimes just these shapes are not enough and limitations occur, as I stated earlier. Not long after I looked into these stencils, I realized that not only some aspects could be improved, but new shapes could also be added to facilitate the users. Previously, I have mentioned that a sharp looking triangle cannot be achieved. Also, none of the existing guides allow for perfectly drawn circles (Figure 3.6). In fact, Tilt Brush has a trick that allows users to create circles, using the "Straight Edge" tool, but the results are limited. Besides this not being a direct access option, the circle cannot be modified in any way besides being scaled, and it can be moved only using the "Selection" tool. A simpler way to fix these would again be a stencil that can be scaled, uniformly or not, which would also allow for the creation of ovals or semicircles and on top of that, provide the ability to place the stencil normally wherever the future circular shape needs to be. Therefore, a triangle and a disk planar stencils would fit these requirements just right. The cube can be used as a planar square as well. Although sometimes the rest of the guide gets in the way, at least visually, and it can become rather uncomfortable for users to keep on using tricks or other shapes for different purposes, instead of having dedicated stencils. A square planar guide would work as a 2D surface, like a blackboard, that would allow users to draw on. These are just a few 2D examples, but the stencils get even more interesting in 3D.

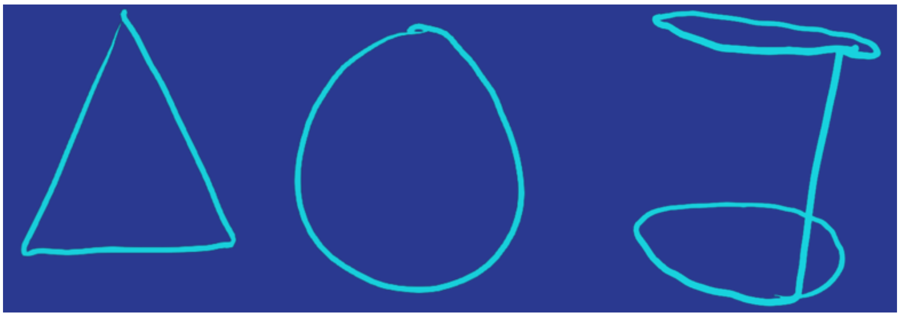


Figure 3.6: A triangle, a circle drawn freely, and a cylinder drawn with the capsule guide.

Figure 3.7: A triangle, a circle and a cylinder drawn with their dedicated stencils.

The capsule stencil is good enough, but its ends are circular. It is quite inconvenient in the current state to draw other shapes such as cylinders, which could be quite useful (Figure 3.6). The only shape with sharp edges and angles is the cube, but it does not allow for much flexibility when it comes to triangular shapes for example. Considering a dedicated 2D stencil for this, I thought going further would only make sense. Therefore, a pyramid, alongside a cone stencil, would cover that too, with the aforementioned transformations possible. All of these new guides together seem to form a solid solution to the question at hand. They could also be used on their own or combined with other stencils, depending on the complexity level required. Regardless, I believe that the provided design will reduce the need for improvisation, as the users are presented with more direct answers and a more facilitating experience (Figure 3.7).

4 REALIZATION

To identify the problem correspondingly, I studied a number of papers and articles (also mentioned in Section 2), so I could fully grasp the concept and see where it is not performing as well as expected. Moreover, a colleague of mine, together with me, put up a small experiment involving Tilt Brush. The participant was a student with a professional background in graphics design, who was allowed a total of 45 minutes to get accustomed to and see if the application itself appealed to him and his objectives. After the experiment was concluded, the observations were highly similar to those previously found during research. The applicant expressed his discontent with regard to some of the present features, including the lack of a wider range of helper tools. Concluding both the research and the experiment, I decided to tackle the area of guidance tools and to see how would I be able to raise their numbers.

4.1 PREPARATIONS

The entire project is done with Unity [8] and the codebase is written in the C# programming language. For the VR part itself, I used an Oculus Quest VR HMD (head-mounted display) provided by the university. Even though the Oculus Quest has its own operating system, it can also be connected to a computer, and that was how I got to properly test every step of the process. The development was done on my personal machine. With the necessary equipment, and as I have previously described the design I had pictured (in Section 3), I investigated how the application worked behind the scenes, with an emphasis on understanding how all the classes related to stencils worked together. I decided to begin working on a prototype as the initial step and incrementally add features to it.

4.2 HOW STENCILS WORK BEHIND THE SCENES

My very first goal was to prove that what I had in mind was possible. I tried implementing a guidance tool that already existed, duplicating the capsule guide. I did that to make sure everything regarding the triggering and spawning of the stencil worked well, without having to worry about its inner workings. After I got this done and I checked that the behavior of the application was in order, I started modifying the copy of the stencil. The first guide I thought about was the cylinder since it was close enough to the capsule itself. I then started writing the code for it but I realized soon thereafter how these shapes actually work. Unity provides a set of colliders, both 3D and 2D. A collider is what defines the outline of an object and fully enables it to react to physical interactions such as collisions. The collider plays a key role in the definition of a stencil. It is what makes the guidance tools work as they are intended to since the collider generates the actual working surface. The collision is a prime factor since the brush's pointer must snap on the surface of the shape and remain there until commanded otherwise. As such, I understood that the existing stencils were actually the four basic 3D colliders available in Unity. Going back to my cylinder process, I needed a proper collider. However, heavily modifying the capsule collider or any other one for that matter to resemble another shape was already too much. Thus, I tackled two options.

4.3 FIRST OPTION : COMBINING COLLIDERS

The first one was to create a new collider by combining those already available. One example would have been to take the capsule and box collider, combine them and only use the part that was a capsule, yet inside the cube. That would lead to a cylinder. However, this method did not go quite as well because the codebase became too complicated. It was difficult to maintain and navigate. For example, many methods were depending on each other and those that detect and read the collider always expected arguments even where none was needed for the new functions. Null was not an option as that would have make the collider undetectable. As so, I decided to back down and revise my progress. I then tackled the subject of 2D stencils, thinking it would be easier to use the corresponding 2D colliders. That did not work, as most of the methods required to get the stencil working were requesting a Vector3, more specifically, three coordinates x, y, and z. Even if one of the coordinates was 0, it still had to be there and a 2D collider was missing one. The simplest solution was to take a 3D collider and simply nullify one coordinate. Keeping this in mind, I first came up with a square planar guide and the implementation took shorter than planned. This was due to how similar its behavior and therefore code was to the already existing cube guide. Then I started working on the planar disk. I thought of the same strategy, and I got to nullify one of the coordinates of the sphere. What that did was to simply flatten the sphere to resemble a disk. While it worked, it did not perform as expected. Manually drawing circles was now possible, but facing only one direction. The disk had a shortcoming in how it could be transformed in space when being used. It would always face the same direction. Unless moving the scene entirely, the disk would not change direction, which made me believe that the space coordinates were at fault. Even with this limitation present, it was a usable solution. The resulting circle could have been later picked up and placed wherever using the selection tool.

4.4 Second option and selected solution

Having these two planar guides working, I decided to approach the concept of 3D shapes once more. The second option available and the most feasible one was using what Unity calls a "Mesh Collider", and its functionality is simple. It takes a mesh asset and automatically computes a collider based on that mesh. I started the implementation of the cylinder guide with this information in mind and I invested time in understanding how the mesh collider would be used codewise. The main point was how to make it detect the collision with the brush's pointer. The process was surprisingly easier compared to how the other stencils work, finally being able to call the collider itself and use it further. This led to the first version of a cylinder stencil implemented with this strategy. In the beginning, the concept of "guide" was not working as the pointer was not detecting any collisions. Further analyzing the problem I realized that the Mesh Collider must be marked as "convex". This reduces the complexity of the resulting collider but enables it to actually interact with other colliders. This meant that the pointer should finally be able to detect the shape. This was the final fix that led to a working version of a cylinder stencil. As such, I settled to use this prototype and modify it correspondingly for the other 3D stencils, the pyramid, the cone, and the octahedron. To maintain consistency, I returned to the 2D shapes I previously implemented and changed their functionality using this type of collider. The disk shape could finally be fully transformed, even non uniformly scaled, and it would properly change direction. Moreover, I started to implement the third planar guide, the triangle one, in addition to the rest and I got it working using the same methods. For the rest of the dedicated remaining time, I tried to improve the tool's precision even more and fix minor problems.

4.5 The new guides

We now discuss what the solution looks like within the application. The first set (Figure 4.1), shows the 3D tools. Then, the second set (Figure 4.2) shows the 2D tools. As can be seen, there are seven stencils in total. As I have mentioned, all of them can be freely transformed, including non-uniform scaling. As their goal is to ultimately improve precision and flexibility and thus make greater challenges possible, I have drawn a set of shapes (Figure 4.3). These are not just a set of random shapes, but all of them have been made using but a few of the new stencils, without combining them. These are a small example of how many possibilities the users have now. For example, the users can draw semicircles, or ovals, using the disk tool, which could not be drawn before as sharp as they can be now. The same goes for the other shapes. All the variants in the picture (Figure 4.3) show the options available.

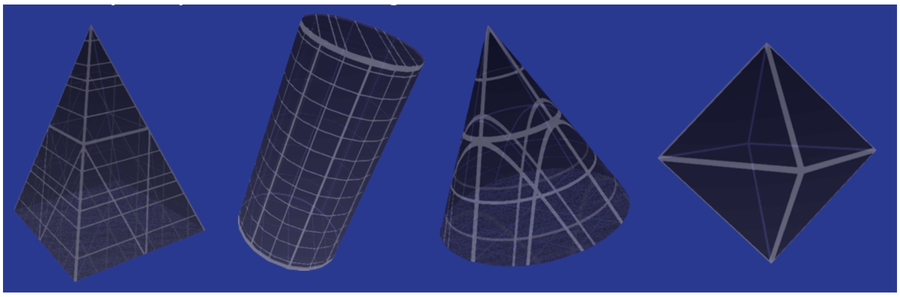


Figure 4.1: The pyramid, cylinder, cone and octahedron stencils.

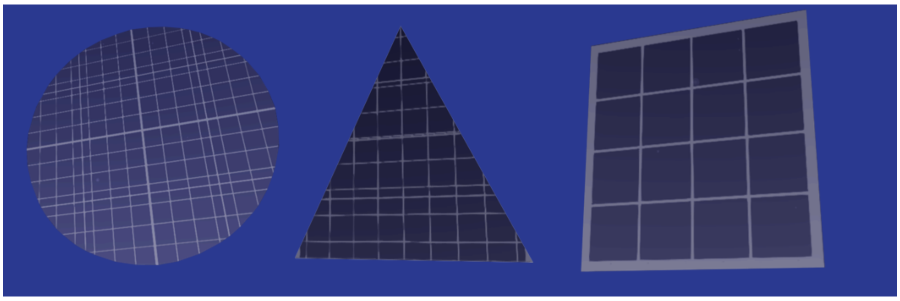


Figure 4.2: The square, triangle and disk plane stencils.

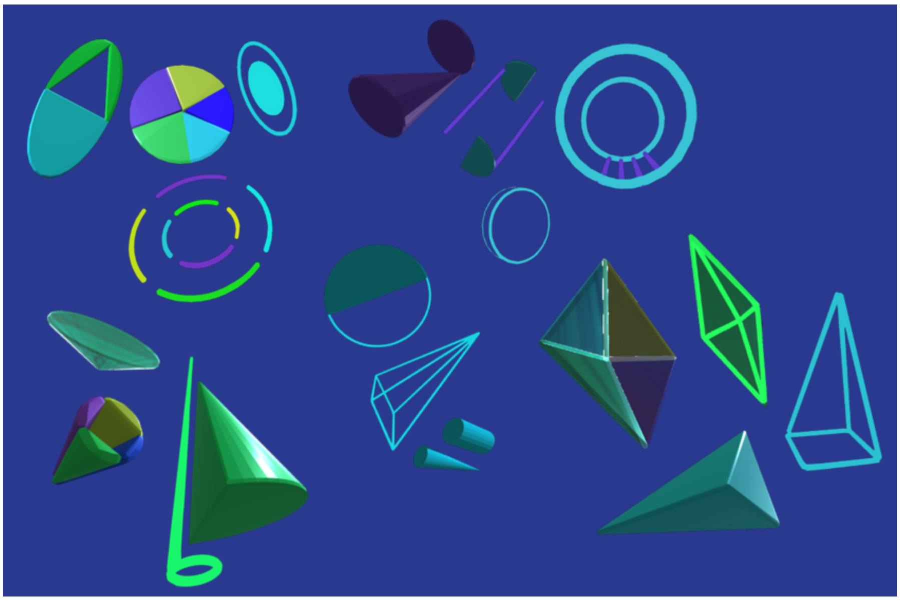


Figure 4.3: Different shape variants obtained with a few of the new stencils.

To reiterate my progress, everything I have done to properly answer the research question at hand was through Unity and Visual Studio Code, for the coding itself. Tilt Brush provided many necessary resources too. Though I faced a number of challenges (Section 4.3), in the end, I managed to achieve what I initially aimed to do and eventually extend the variety of guidance tools Tilt Brush provides.

5 EVALUATION AND RESULTS

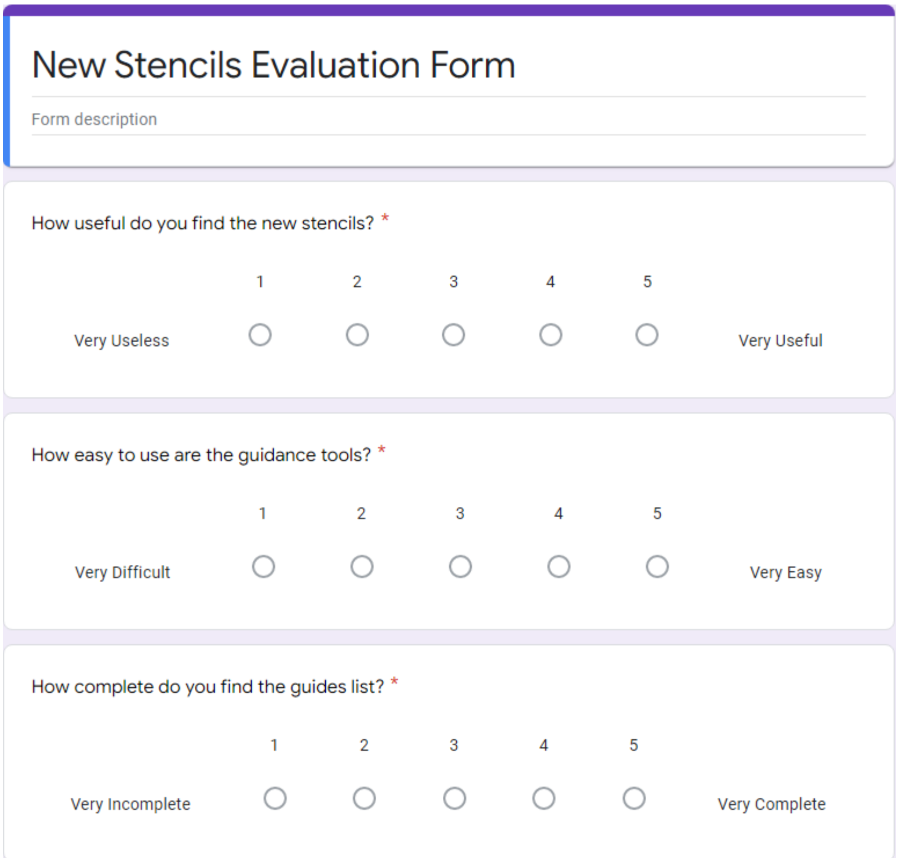
In order to test the additional features of the application, I conducted a new experiment involving both versions of Tilt Brush. For this, I gathered a small group of four students with different levels of experience. Two of which have never used Tilt Brush before, one did have previous experience with the application, and the last one was the same which helped in conducting the initial experiment (Section 4).

5.1 HOW THE EXPERIMENT WORKED

The experiment involved each participant using Tilt Brush for 10 minutes, without any set goal, to allow them to get accustomed to how the application and its features work. This was especially useful for those that have not used it before. Then half an hour was dedicated to the experiment itself, using both versions of the software. As such, they spent 15 minutes drawing something of their choice using the old version, and 15 minutes making the same drawing but using the new version. They were allowed to only use the brush freely or with the existing guidance tools. I considered this restriction to be quite an important one, as the focus was then solely on the changes brought forth by the new stencils. After each participant depleted their available time, they were asked to answer a survey aimed at assessing their experience.

5.2 EVALUATION RESULTS

The survey the participants had to complete was composed of 10 questions, dedicated to properly assessing the experience and the stencils themselves. You can find the questions below (Figures 5.1 – 5.3).



New Stencils Evaluation Form

Form description

How useful do you find the new stencils? *

	1	2	3	4	5	
Very Useless	○	○	○	○	○	Very Useful

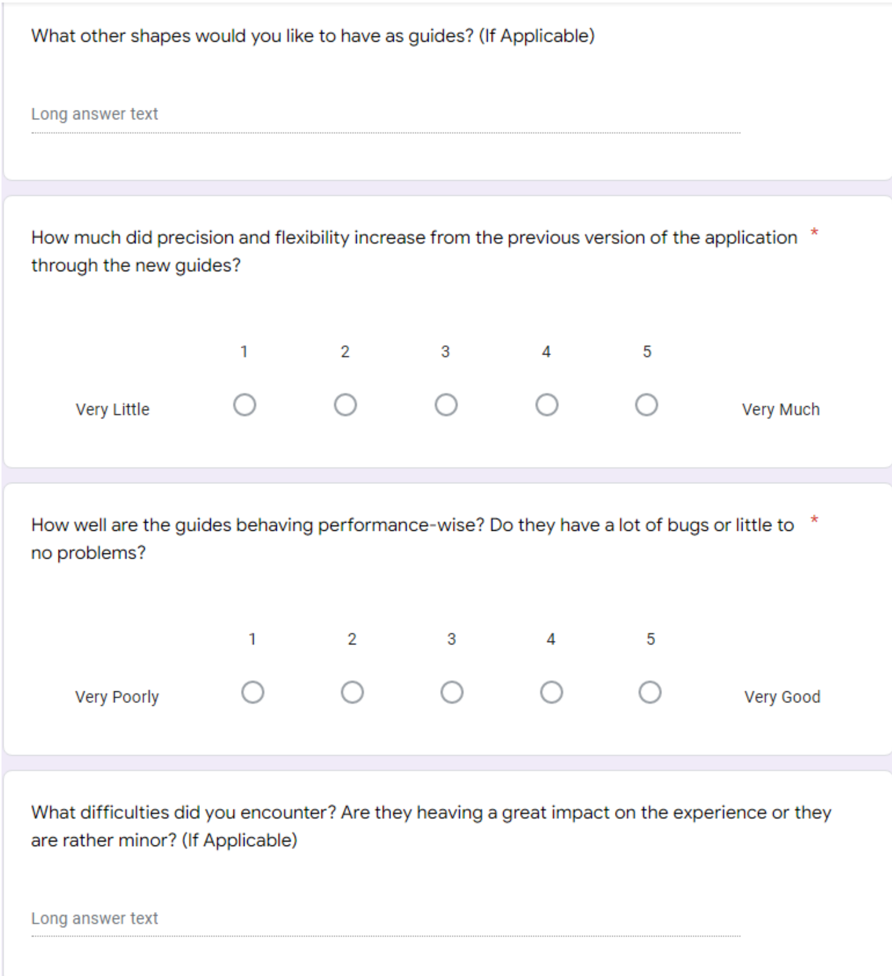
How easy to use are the guidance tools? *

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	Very Easy

How complete do you find the guides list? *

	1	2	3	4	5	
Very Incomplete	○	○	○	○	○	Very Complete

Figure 5.1: First page of questions.



What other shapes would you like to have as guides? (If Applicable)

Long answer text

How much did precision and flexibility increase from the previous version of the application through the new guides? *

	1	2	3	4	5	
Very Little	○	○	○	○	○	Very Much

How well are the guides behaving performance-wise? Do they have a lot of bugs or little to no problems? *

	1	2	3	4	5	
Very Poorly	○	○	○	○	○	Very Good

What difficulties did you encounter? Are they heaving a great impact on the experience or they are rather minor? (If Applicable)

Long answer text

Figure 5.2: Second page of questions.

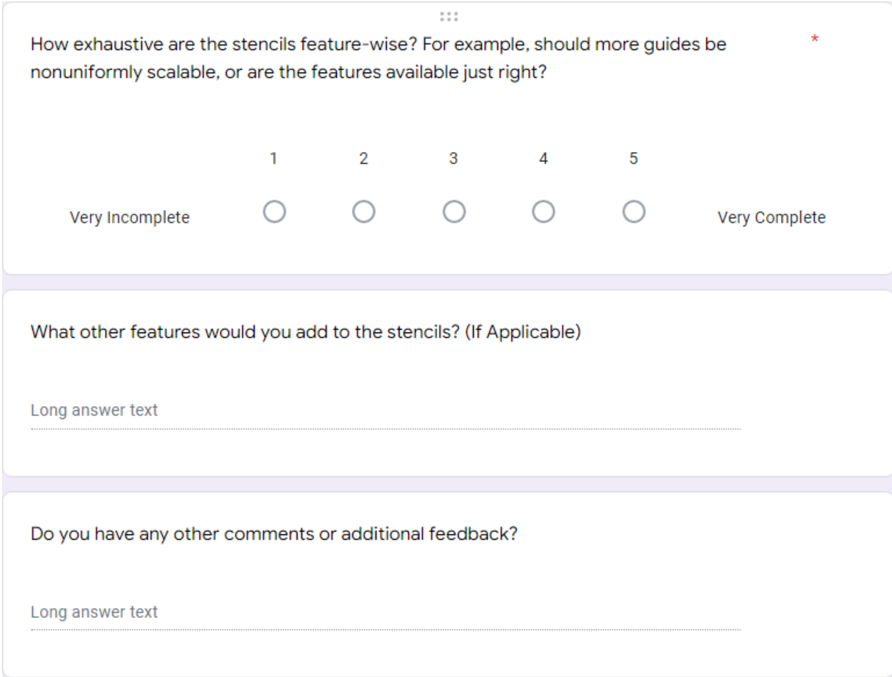


Figure 5.3: Last page of questions.

The completed version of the survey can be found in the Appendix. However, in order to point out how significant the change is, I show some of the questions and their responses. For example, I asked the question that stands at the core of this project, how much did precision and flexibility increase (Figure 5.4)? As can be seen, the results show that the update is rather significant and that these aspects have, indeed, been improved. Another question (Figure 5.5) asks the users about the stencils' performance. The users were satisfied, reporting but a few minor problems. As for the stencils' features and their available options, the users had little to no complaints (Figure 5.6).

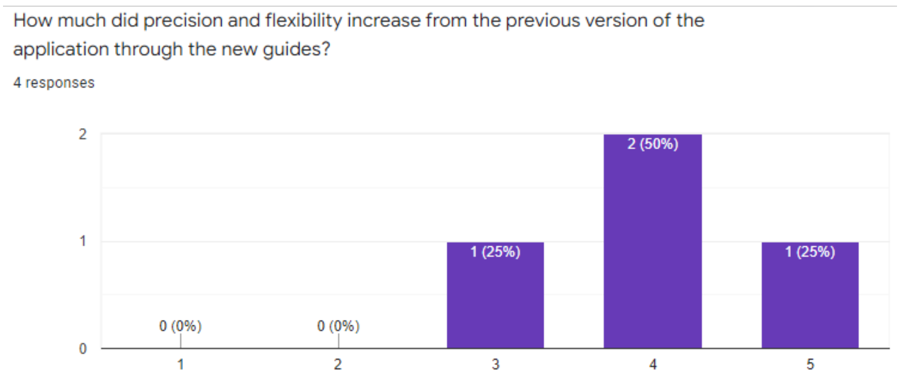


Figure 5.4: The question related to how much precision and flexibility increased.

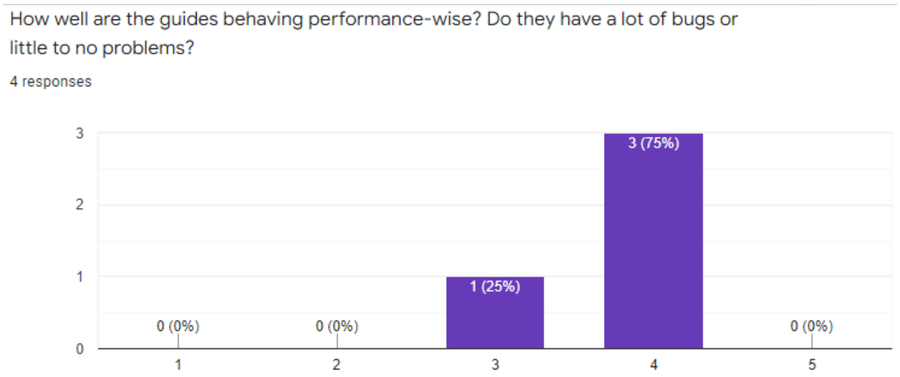


Figure 5.5: The question related to the performance.

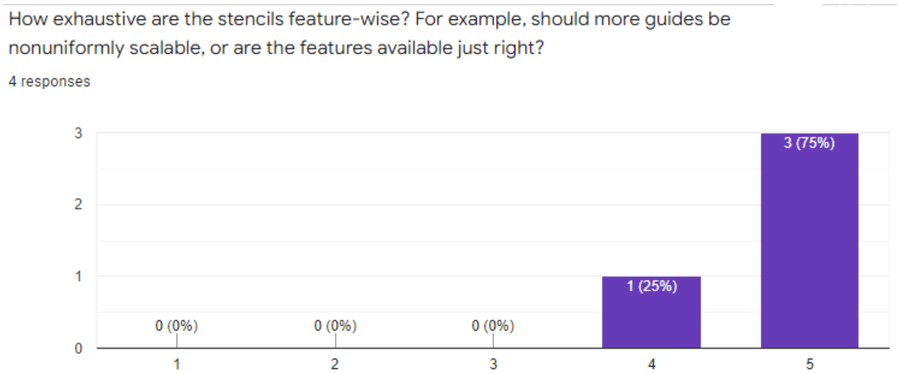


Figure 5.6: The question related to the features.

5.3 ART RESULTS

As can be seen, the results are very much positive and the users were ultimately satisfied, noticing the difference between the two versions and the improvements brought forth. Further feedback can be found in the Appendix. However, the aforementioned experiment was not the only way through which I tested the new stencils. In Figures 5.7 – 5.9 three different scenes can be seen. All of these were made using only the new guidance tools. The process was fast and simple, and the level of precision and freedom with shapes and different variations can be seen. Looking at the forest scene for example (Figure 5.7), some shapes can be easily noticed. The trees are made of cylinders, their crown and the pedestal are cones. The crystal itself is an octahedron. The ground is a planar square. The shield is a planar disk, and the blade of the sword is a pyramid. Other details are more difficult to see. The ornaments of the shield are also disks and a pyramid, the hilt of the sword and the arrow body is a cylinder, the paper is a square plane, followed by the tip of the arrow which is again a pyramid, and the feathers at its other end which are triangle planes. This is the level of detail, accuracy, and flexibility I set out to achieve with these new tools.

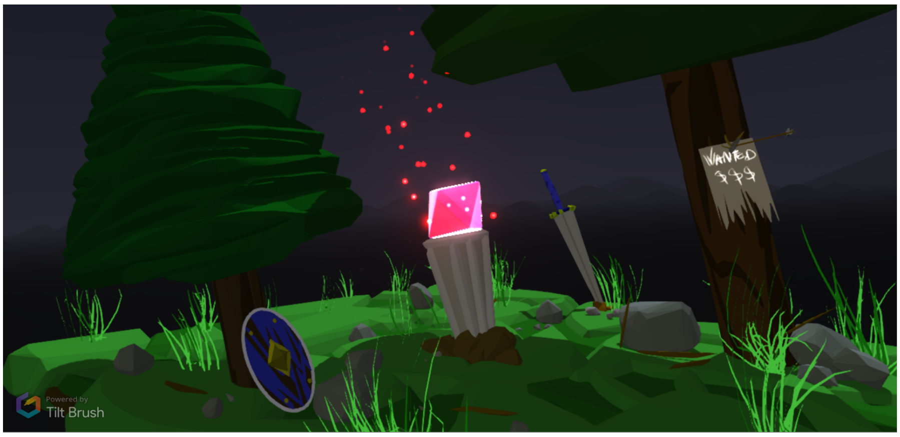


Figure 5.7: This scene was realized using all the new 7 stencils.

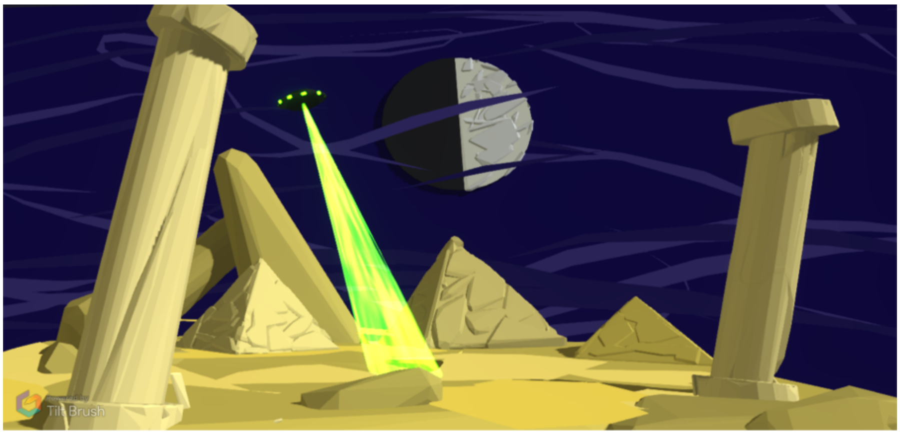


Figure 5.8: This scene was realized using 6 of the new stencils.

Figure 5.9: This scene was realized using 6 of the new stencils.

6 CONCLUSION AND FUTURE WORK

I believe that the solution proposed was not only feasible but a step in the right direction. I started off by learning the complex code base and how it all works. I learned more about Unity while practicing and creating mock functions inside Tilt Brush to demonstrate that it can be done. I read papers that helped me understand the limitations encountered in Tilt Brush and other 3D modeling and sketch applications. That process led me to tackle the idea of guidance tools and to further expand on the concept with a solution for the found shortcomings. Eventually, I set out to make the concept happen. Throughout the whole process toward the final version I encountered many challenges and bugs to fix, but I eventually managed to overcome the majority of them. What I obtained is a solid update in increasing the precision and the freedom users have within Tilt Brush. These arguments are backed by the evaluations I conducted and the results reported.

Although, there is always room for improvement. Following the feedback received through the survey (found in the Appendix), I set out to address the reported problems. While they are rather minor fixes, time did not allow me to fix everything, so, I came up with a possible future work plan. For example, there is a bug that involves the texture of two stencils, the pyramid, and the cone, where the base surface is a bit too noisy. This is a strictly visual bug, however, and it does not influence performance. Another requested fix would be to tweak the behavior of the planar disk, as sometimes the pointer slips too easily on the other side. But the future work could involve new features as well. For example, an update could add a new feature that would allow users to snap more guides to one another within the app, creating a custom-made shape. I think this would be another step in the same direction of improving accuracy and the freedom provided to the user.

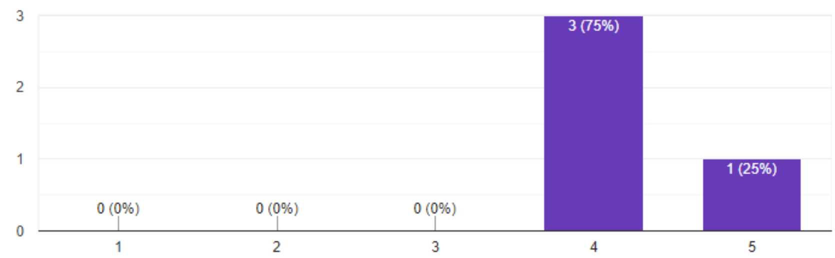
Nevertheless, considering the all results, examples and the evaluation conducted, I can conclude that the goal to improve precision and flexibility was achieved. The stencils proved to be intuitive, easy to use, and exhaustive while maintaining great performance. All these aspects point out that the new stencils provide a split answer to the research question at hand and fulfill their purpose.

APPENDIX A

The complete user evaluation, including the feedback received.

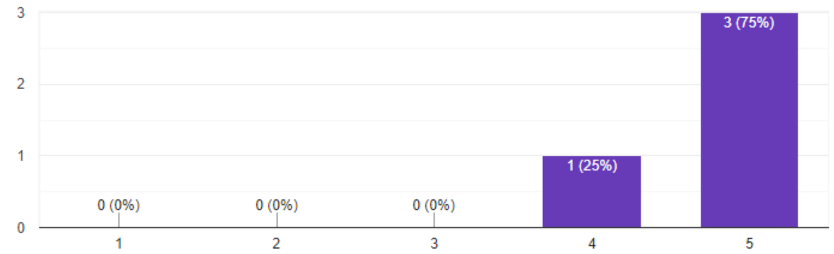
How useful do you find the new stencils?

4 responses



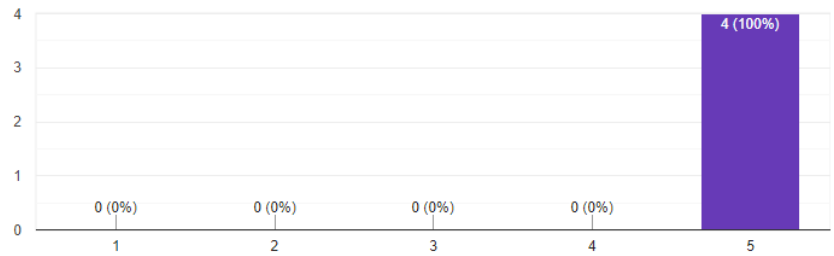
How easy to use are the guidance tools?

4 responses



How complete do you find the guides list?

4 responses



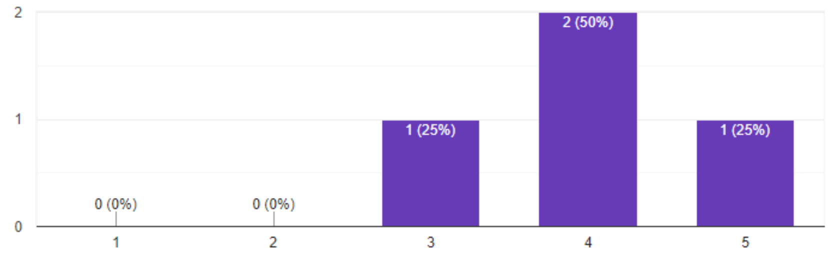
What other shapes would you like to have as guides? (If Applicable)

1 response

None. The list is big enough.

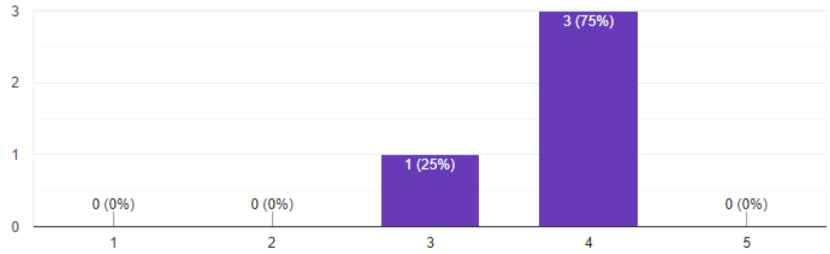
How much did precision and flexibility increase from the previous version of the application through the new guides?

4 responses



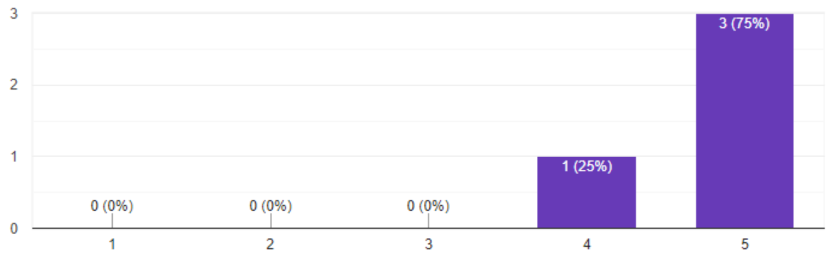
How well are the guides behaving performance-wise? Do they have a lot of bugs or little to no problems?

4 responses



How exhaustive are the stencils feature-wise? For example, should more guides be nonuniformly scalable, or are the features available just right?

4 responses



What difficulties did you encounter? Are they heaving a great impact on the experience or they are rather minor? (If Applicable)

4 responses

The disc is somewhat problematic in that the brush can go around to the backside, creating artifacts. This behaviour is not necessary, it is already a 2D plane, so whether one is snapping to the front or back the result is the same, there's no need for transitioning between faces. This is probably the single biggest issue, but it's not really that big of a deal. Other minor issues are mostly texture-related.

Sometimes the pointer does not go as smoothly on the cylinder but it does not have a huge impact on precision.

Cylinder shape - the pointer sometimes stutters. Also, on the disk plane the pointer sometimes slips on the other side

Minor bugs, like sometimes when I want to rescale non uniformly it ends up scaling uniformly, but this happens when the shape is very small.

What other features would you add to the stencils? (If Applicable)

0 responses

No responses yet for this question.

Do you have any other comments or additional feedback?

1 response

2 shapes are having a small bug with their texture

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