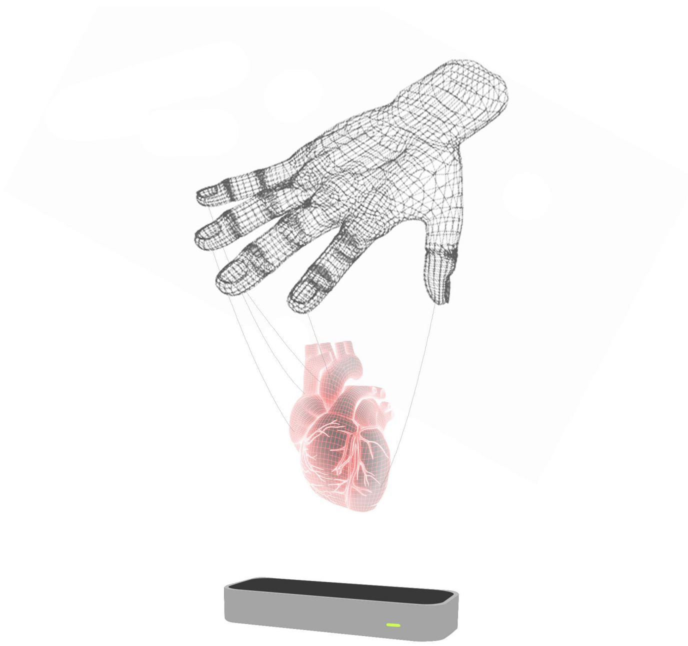
Leap motion for sterile manipulation of 3D models

European Project Semester Group F

Autumn Semester 2017



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Abstract

Performing surgeries with 3D models are to an increasing extent becoming normal practice. The common tool for manipulating these 3D objects is with a computer mouse, which is not designed for a three-dimensional virtual space. Thus, the use of a computer mouse in combination with 3D objects is not intuitive. This is the reason for experimenting with new input devices, such as the Leap Motion device, to enhance the workflow of controlling 3D objects. Therefore, the project developed a program for manipulating these models in *Unity* with the Leap Motion device. A user survey was conducted to identify issues and help understand how the surgeons use and interact directly with a 3D object in a sterile manner. The results of this project strongly support the fact that the usage of the Leap Motion is more efficient in various tasks than a computer mouse. With this the Leap Motion stacks upon revolutionary 2D imaging in medical practice, and thus is an important piece in future medical care and surgery.

Acknowledgments

The progress we made with the project “Leap motion for sterile manipulation of 3D models” required a great amount of guidance and assistance by students, professors of HiOA and staff members of the Rikshospitalet University Hospital. We felt privileged to do research on project, which is vital for surgery.

First, our deepest appreciation goes to our supervisor Louise Oram whose support, guidance and solicitude were innumerably valuable throughout the semester.

Second, we would like to thank our professors Nina Hagerup, Tengel Aas Sandtrø and Petter Øyan, for their well organized and supporting lectures. We are also grateful of Brit Balgaard, for her continuous support throughout the semester.

Our gratitude also needs to be expressed to the staff members of the Oslo University Hospital. Louise Oram established communication between the hospital and the project team. In addition, we felt privileged to observe two surgeries.

We also thank the information technology consultancy Sopra Steria for letting us visit one of the most beautiful working places in Oslo. Besides, they provided us constructive feedback and the possibility to test mixed reality devices, such as the Hololens.

Our project team is very grateful, that the Høgskolen i Oslo og Akershus made this project possible for foreign students, by offering a European Project Semester.

We cannot forget to thank all participants who participated in our user survey.

Glossary

SDK	A Software Development Kit is a set of software tools.
3D object	A mathematical representation of any surface of an object in three-dimensions.
collider	An invisible frame of a 3D object which detects collisions.
Unity	A game engine for developing video games and simulations for multiple platforms.
C#	A object-oriented programming language.
Leap Motion	An American company which manufactures a sensor device for hand movements.
HiOA	Oslo and Akershus University College of Applied Sciences
Unix	A family of various operating systems.

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1. Introduction

Leap Motion is a computer hardware device which can sense hand movements. Its application is versatile, yet still commonly used as an input device for computer games. The University Hospital of Oslo recognized the potential of the Leap Motion Device to improve their workflow in 2013-14 and started research into it. They proposed an idea for a project to the Oslo and Akershus University College of Applied Sciences. Thus, students are able to strengthen their skills in a professional environment and help succeeding the project.

The mission of the project "Leap motion for sterile manipulation of 3D models" was to create a program combined with a Leap Motion device, in which one can manipulate 3D models of organs without touching a computer mouse.

The Leap Motion Device and the game engine *Unity3D* were used to develop a program for manipulating 3D models in *Unity*. The program should allow the user to interact with a 3D model in various ways. A major goal of the project was to provide cross-platform compatibility on major operating systems (Linux, MacOS, and Windows). The main aim of the group was to develop a functional prototype, which one can further develop after the project's termination. To ensure further development of the project's program, the project group thoroughly documented the software code, including the thought and motivation of various taken actions.

Additionally, a user survey with the final prototype was conducted. Clarification of the user survey's methodology and the discussion of its results are available in the report.

The report contains a project evaluation, the methodology of the user survey and the developed program as well as the results. At the end of this report there is a discussion about the developed program and its implemented features and gestures. Moreover, the report includes the project's sustainability after the termination.

2. Project Evaluation

2.1. Relevance

Assessing the present situation in which surgeons perform surgery is vital to identify issues and desires for this project. Upon this assessment, the project team was able to formulate achievable goals and specific objectives.

Presently surgeons must remain sterile while performing surgery, thus various tools and objects that they get in contact with have to be sterile too. In that case, operating a computer mouse and a keyboard in order to manipulate 3D objects is done by an assistant or a nurse. Based on a previous experiment (Balakrishnan, R et al., 1997), executing tasks, such as rotating or moving a 3D object of an organ with a computer mouse is not intuitive and ergonomic. This becomes further apparent when the surgeon directs his or her assistant to manipulate the 3D object. Describing a certain move of a 3D images instead of a 2D image appears to be more complex. Hence, it is more likely to misunderstand each other, resulting in possible errors.

In addition, one might argue that the current situation of manipulating 3D objects with a computer mouse requires patience and time. Because of that, it is clear to say that the focus shifts from the patient to manipulating a 3D object. The efficiency of performing various tasks in 3D space can be enhanced by utilizing the computer mouse with a keyboard, to execute shortcuts, thus improving the overall workflow. It seems unlikely that this approach is used by the majority of surgery assistants or nurses, due to the presumably lack of knowledge in the software used for displaying 3D models. In addition, the group believes, the lacking motivation of increasingly utilizing 3D objects prevents it of enhancing the existing workflow. It is obvious to say, that medical imaging for the human body revolutionized clinical practice in the past ten to twenty years. This project aims to build upon present techniques.

2.2. Effectiveness

Evaluating the effectiveness of various approaches and outcomes in correlation to the project design is key to understand the justification of certain actions.

In the first quarter of the project's time frame the project members agreed upon improving the prior project in *Unity*. Limited resources and documentation restricted the approach to enhance the software. Since the software was incompatible with the project's members Unix computers, it is safe to say that this approach would not have met the initial aims. Thus, the project team decided to reprogram the software in Unity with an older SDK, in order to provide cross-platform compatibility.

At this moment, the latest SDK was exclusively on *Windows* available. Consequently, compromises had been made by selecting an older software development kit. Various features and functionality were not available in the SDK version the project team chose. This approach facilitated developing the program and dividing tasks between all four group members.

This group received supportive feedback from two mentor meetings with professors of HiOA, in order to assess and solve issues of the project. In addition, all four group members attended courses in English and Project Management throughout the project cycle. The project's supervisor, Louise Oram, arranged a meeting with the project's core members and staff members of the Oslo University Hospital Rikshospitalet, in order to see a surgery. Understanding the environment in which a surgery is being performed was crucial for designing the software.

2.3. Impact

To ensure the project's long-term impacts, various objectives have been executed successfully. Firstly, the program was written in the object-oriented programming language C#, appropriate for *Unity*. Secondly, the source code of the software is thoroughly documented. Lastly, instructions for installing the software have been made public online to ensure a fully functional software on multiple operating systems.

It is certain to say that the project's outcomes will benefit surgeons and nurses directly, due to the improved workflow. Patients are considered to be indirect beneficiaries.

2.4. Stakeholder analysis

The following paragraphs will present the main stakeholders, from *core* and *primary* to *secondary*.

Our unique Core, Louise Oram, works in the hospital Rikshospitalet as a computer scientist. In the project, she acts as an external supervisor. She proposed the Leap Motion project and assisted the group by giving continuous constructive feedback and establishing communication between Rikshospitalet, the company Sopra Steria, a company specializing in virtual reality, and the project group.

Primary Stakeholder: Rikshospitalet is considered as the project's main client, due to the development of a software, designed for surgeons working there.

Secondary Stakeholders: HiOA, the University College provides the possibility to enroll in an European Project Semester. Patients which will be treated by surgeons who use the project's software to view the 3D models, are also considered secondary Stakeholders. The European Commission, which offers the EPS, might also be interested in the results of this project. Potential customers, such as other hospitals that want the project's product, can also be considered part of this group. REK, the Regional Committees for Medical and Health Research Ethics, is also considered a secondary stakeholder. Finally, the company Sopra Steria, which supported the project with creative approaches and feedback, is an important stakeholder.

At the beginning, the project team decided to consider professors as stakeholders, but they were rather considered as advisors, guiding the work and giving feedback.

The primary stakeholders are mainly interested in utilizing the program in the near future. Their aim is to use the program to enhance the workflow of surgeries, thus saving valuable time in surgeries and medical practice.

The secondary stakeholders are rather keen to see the project's success. They are not necessarily concerned about how the program functions, rather the utility of it and the impact the program has on its environment is more important for them.

The primary stakeholders are active participants, which can influence the projects decisions. Staff members of the HiOA College only inform the project team in giving them feedback, hence shaping the outcome of the project.

3. Methods

3.1. Assessment of the project's initial situation

The current project group working on the project "Leap motion for sterile manipulation of 3D models" is not the first group working on this project. There have been two groups before, who participated in the European Project Semester, working on this project. The members of this team received the results of the groups, which were working on this project in the previous semesters. The initial idea was to continue working on the prototypes and results given by the previous project groups. The previous groups were mainly working on *Windows*. Since the dominating operating system in the current project group was *Mac OS*, the current project group was not able to make the given program work on their computers. To run Leap Motion the code requires a SDK (Software Development Kit) which transforms the signals from Leap Motion into readable data for the computer. There are several SDKs, which have been developed by the Leap Motion company over the past years. All of them have the same functionality, but the newer the version is the more optimizations and new features have been implemented to the SDK. The latest SDK at this time, which runs on *Windows* and *Mac OS* is the SDK 2.3. The newest SDK, called Orion, only runs on *Windows*. Three of the four members of the team own an *Apple* computer. The first idea was to use the SDK Orion since it was the newest SDK, but this would require three team members to install *Windows* on their computers or run it as a virtual machine (VM). It can be much slower to run programs inside a VM, which would have caused the problem, that Unity might not work as fluent as it should. After that, the team agreed to use the SDK 2.3 even if it was older than the SDK Orion.

3.2. Development

3.2.1. Features

As the goal of the project was to build a simple prototype, the team chose to implement only the basic functions for 3D model manipulation: Rotating, Translating and Scaling. However, the Translation movement has evolved to be more like a Grab and Move for a better user experience.

Moreover, another feature had to be implemented to help the user interact with the application: a button to reset the model to its initial state.

3.2.1.1. Rotation

Objective of the feature

The 3D model is static. To see the parts of the organ that are obscured in the current viewing angle, a rotation of the object will be needed.

Conception

The first idea was to rotate the object by moving the hand around it, but not touching the object. The 3D model would follow the hand’s rotation as it is grabbed from a distance. The main problem of this interaction method is that it would be unclear for the user if the gesture is activated.

After reflection, a second idea was to put the hand inside the object and rotate it. The model will mimic the hand’s rotation.

The second idea was easier to implement, and appeared more intuitive for the team so it was the gesture chosen for this feature.

3.2.1.2. Scaling

Objective of the feature

The 3D organ can be really complex. Thus, surgeons may want to zoom on a specific part of the model for a better visibility.

Conception

At first, the idea was a pinch gesture inside the model with one hand. Then the user simply has to move the hand pinching toward or away from the user.

A second idea was a pinch gesture with both hands inside the model. Then the movement would be to separate the hands pinching to zoom in, or bring them closer to zoom out. This action would scale the 3D model: enlarging it to zoom in, shrinking it to zoom out.

This concept provides more advantages than the first one. The movement would mimic the zoom gesture on a tablet or smartphone, an action nowadays omnipresent. Besides, the concept would avoid displacing the viewpoint. Thus, the viewpoint would keep its static behavior.

3.2.1.3. Grab and Move

Objective of the feature

At the beginning, no translation of the object was required. However, if a zoom has been performed, the surgeons may want to look at another part of the organ that is not visible. The avoid zooming out, a translation might be executed.

Conception

At first, the idea was fist gesture inside the model. Then the user would only move the fist to drag the object. The drag would only translate the model without any rotation.

Nonetheless, the fist gesture was not well detected by the Leap Motion. A thought was to adopt the pinch gesture used for zooming. The pinch would act as a grab gesture. The movement then would execute the same translation, but would also be associated with the rotation. This final gesture would represent a real-life behavior: grabbing an object with the hand and moving it around.

3.2.1.4. Reset Button

Objective of the feature

The 3D object will be displaced in the 3D space and the camera is static. Thus, after several manipulations, the organ might be displaced in the corners of the screen or even out of it. The Leap Motion controller does not have a wide range of detection. Therefore it is complicated to have the hands precisely detected when they are at the screen's edges. To avoid this problem, one solution was to create a button to reset the object to its initial state. Its position, rotation and scale would be reset.

Conception

To activate a button with virtual hands in a 3D application is not a common task. Indeed, people nowadays are mostly utilizing their hands to interact with 2D user interfaces, for example smartphones and tablets. Therefore, several approaches were studied.

The Leap Motion Playground applications were tested to study the different ways of handling a button with virtual hands. In these cases, the buttons were 2D icons. To activate one, the user had to hover his index finger one second on top of it. This solution was sometimes working perfectly. However, it was occasionally difficult to activate the button with the finger hovering over it while nothing was happening. Hence, another approach had to be found. The thought was to create a 3D button and to use the physics of the hand to push it. An article from Felix Noller (2016), a human factor researcher, explained a way to implement a 3D button using Leap Motion and Unity. The button is pushed by the hand and is going back to its original position when the hand leaves it. This last solution was more ergonomic as only 3D interaction will available for the users. They will not have to deal with both 2D and 3D interactions.

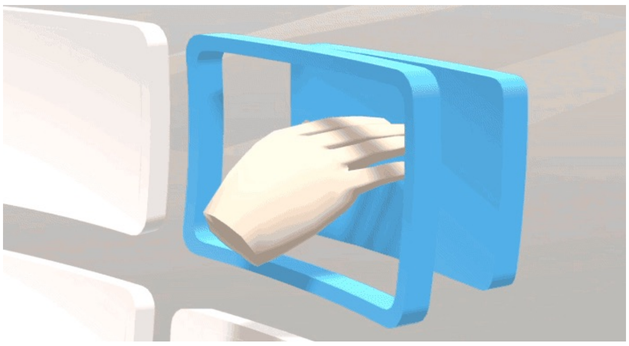


Figure 1: hand pushing a 3D button

3.2.1.5. Feature cohesion

The features have been conceived to be easily associated with others. The rotation can work alone, but is executed as well when the user grabs the model. Besides, the zoom feature is using the pinch gesture of the grab and move.

More importantly, the features have been implemented to be used in a same manipulation, one after another. The goal here is to give the user a sensation of freedom manipulating the organ: as it was a real object he could grab, bring closer to his eye, rotate and scale with intuitive gestures. The reset button would be present here to grant a rapid way to go back to a standard position of the 3D object and help the user avoid feeling lost.

3.2.2. Programming

3.2.2.1. Working with Unity3D

The previous group that worked on the project chose to associate Unity3D with the Leap Motion SDK. Unity3D (most commonly called "Unity") is a powerful 3D Engine used mostly for game development but also for any 3D physical interaction software. It has an ergonomic editor and a complex API (set of classes, methods and functions that can be used for programming). A multitude of assets and plugins made by developers are also available to add more features to the engine. One of them is the Leap Motion plugin, it retrieves the Leap Motion data and gives it to Unity. It also allows the developer to create the hands in the 3D scene so it can play with the 3D models.

With all these advantages, *Unity* has been kept by the team and used for the software development.

3.2.2.2. GitHub and SourceTree

When a software is developed, it is essential to utilize a version control tool. This will save several versions of the software on a server, they might be seen as backups. Therefore, if one or various files are having problems, they can be restored to a previous version.

Besides this, version control is an efficient tool for team working. Every developer is able to develop on the same project without having code conflicts with the others.

To choose which tool should be used for the application, the experienced developers of the team selected Git with the GitHub platform. A web platform used to store and share projects with other coders. A project management tool is present in the website as well. In addition, the software SourceTree has been chosen to provide a Graphical Interface with Git.

3.2.2.3. Workflow

The project has been realized in 3 phases: Analysis, Programming and Surveying. For each part, the group was split into subgroups or individuals working on subcomponents to gain in efficiency.

Firstly, the team had to analyze the project to find its goals. The application of the previous group has been analyzed to see what can be done with it. Several researches on the internet have been done on Leap Motion to expand the team's understanding on the subject and to look for various approaches. Finally, one team member learned how to work with Unity following a few tutorials.

Secondly, when the goals were defined, the team started coding on the application. Each member had a feature to implement.

Lastly, when a first prototype was running, a part of the team started working on a user survey. The goal was to test the application and to study the efficiency of Leap Motion. The other members continued coding on the application for optimization and to finalize the documentation.

3.3. User survey

3.3.1. Methods of the user survey

After most of the programming and development part was done the project group had the idea to conduct a user survey to assess people's first-time experience with the Leap Motion device. There are several motivations to carry out a user survey:

1. The goal was to see, if the implemented features are intuitive or if some gestures or features need to be reconsidered. It is always necessary to do early-stage testing of a created product, so one can identify mistakes, flaws and design issues. Time and money was limited, so the project group wants to give a constructive feedback to the upcoming group working on this project about the created features. The thought behind this is to establish a comfortable project start for the upcoming group.

2. By looking at how people interact with a prototype of one's product one will get a great amount of information, which is beneficial for future changes. Conducting a user survey and User testing reduces time and money investment. By having users testing one's product you will get feedback. In the case of the project group, the feedback was not only given by speaking to the people, who participated in the user survey, but also by observing how the participants utilized the Leap Motion device in combination with the developed program. The information that was collected is important for the upcoming group working on this project.

3. By conducting a user survey, one gets an unbiased perspective of other people. Due to the biased perspective of the project team members, it was necessary to gather feedback and opinions from people outside the project team. The reason for this is to spot possible flaws of the product, which might not have been obvious for the project team, due to their biased perspective.

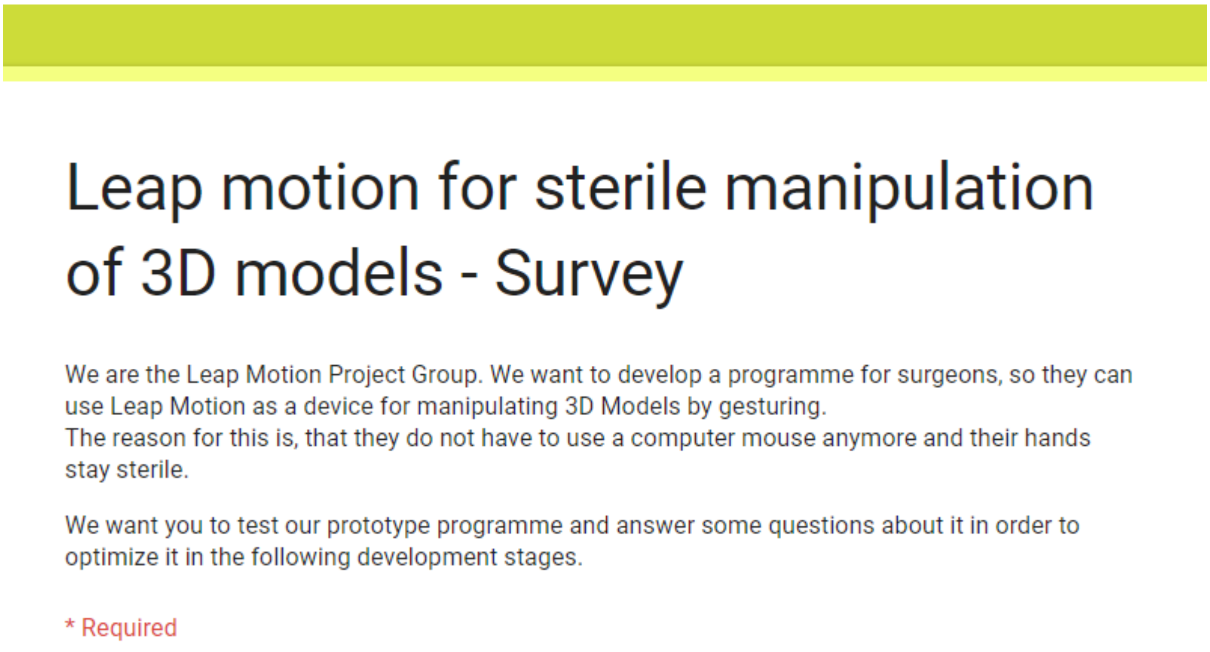
Signing a Consent Form to participate in the user survey was required.

The Consent Form included the following information and can be found in the appendix.

- Background and purpose of the survey.
- What does participation in the survey imply?
- What will happen to the participant's information?
- A confirmation, that it is voluntary to participate in the survey.

In the following part the user survey will be explained. The user survey was created with *Google Forms*. In addition, screenshots of the user survey will be displayed.

3.3.2. General Information



Leap motion for sterile manipulation of 3D models - Survey

We are the Leap Motion Project Group. We want to develop a programme for surgeons, so they can use Leap Motion as a device for manipulating 3D Models by gesturing.
The reason for this is, that they do not have to use a computer mouse anymore and their hands stay sterile.

We want you to test our prototype programme and answer some questions about it in order to optimize it in the following development stages.

* Required

Figure 2: General Information about the Leap Motion Project

In the beginning of the user survey the project group briefed each participant about the Leap Motion project and the goals of the survey. It needs to be mentioned, that some of the following questions require an answer, while others do not. Questions, which requires an answer are marked with a red star. At the start of the survey it was mentioned, that only honest opinions and answers to the question can help the project improving the program.

3.3.3. Personal Information

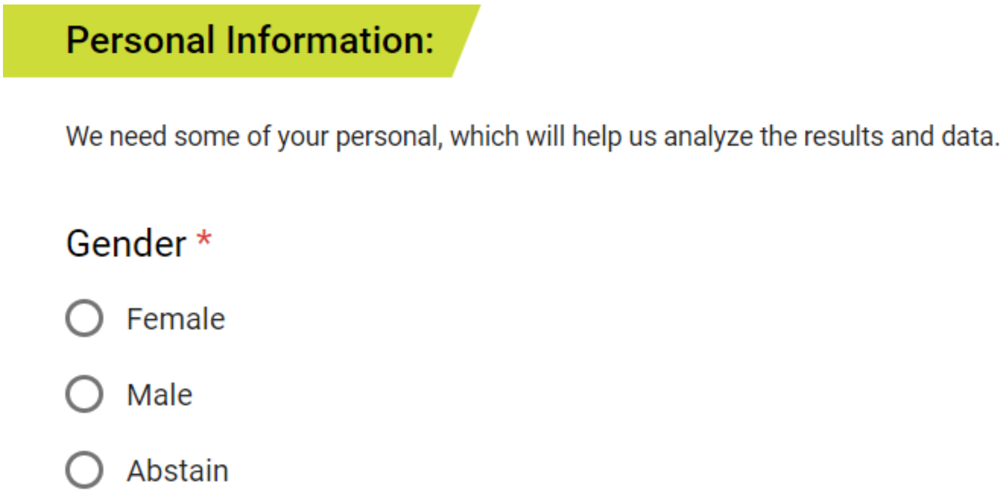


Figure 3: Start of the collection of personal information. Asking about the gender.

In this part the participants should click whether they are male or female. It was also allowed to refuse giving an information about your gender by clicking “Abstain”.

The goal of this question was to see if a certain gender is significantly better in working with Leap Motion.

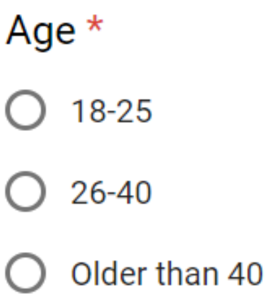


Figure 4: Asking about the age.

In this part of the survey the participants were asked about their age. The reason for asking for age brackets, and not for the specific age of the survey participant, was to make the survey more anonymous.

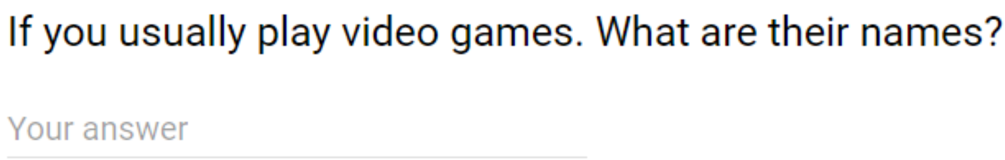
These age brackets were chosen for a specific reason. The bracket 18-25 is considered for students, who might be in their bachelor’s program. The bracket 26-40 is meant for older students and people, who might have a job. The option “Older than 40” is meant for people, who did not grow up with current modern technology and therefore may be less comfortable or familiar with it. The reason for this question is to see, which age bracket can handle the Leap Motion program the best.

How often do you play video games? *

- Every day
- 3-4 times a week
- Once a week
- A few times per year
- I do not play video games

Figure 5: Asking about how often the survey participant is playing video games.

Here the participant is asked about how frequently one plays video games. The motivation for asking this question was to see if people, who often play video games are superior in interacting with the Leap Motion device in combination with the project's program.

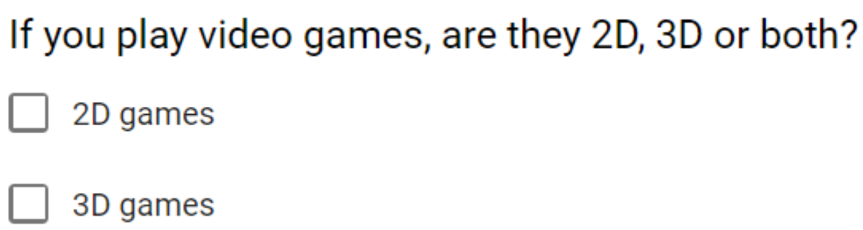


If you usually play video games. What are their names?

Your answer

Figure 6: Asking about which video games the participant plays.

There is a simple reason for asking this question. The participant might say that she or he is playing video games every day. If one is already experienced in playing 3D games, he or she might perform better, due to a better sense of orientation in virtual 3D space. The goal of the questions in Fig x+3 and Fig x+4 was to find out if one plays video games and which video game, to see if it would help them interacting with Leap Motion more swiftly and reliable, so the project group could see if they are acting more intuitive with the Leap Motion device.

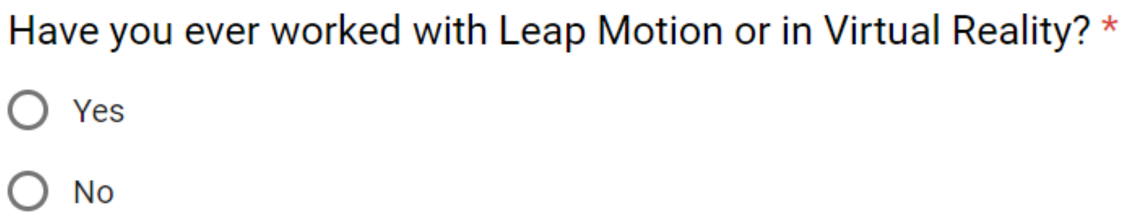

If you play video games, are they 2D, 3D or both?

☐ 2D games

☐ 3D games

Figure 7: Asking in how many dimensions the video games are played.

This question is a simplified version of the prior question. If participants are uncertain about filling out the previous question with a specific game title, this question broadly indicates whether one is familiar with a 3D or a 2D environment.

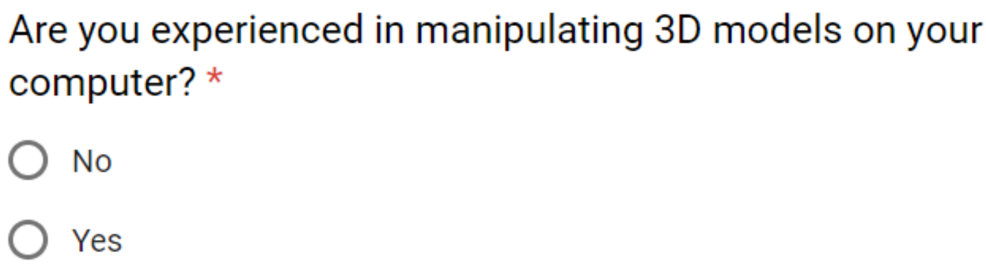

Have you ever worked with Leap Motion or in Virtual Reality? *

○ Yes

○ No

Figure 8: Asking about having experience with Leap Motion or Virtual Reality.

There is a simple reason for asking about the participant having any experience with Leap Motion or Virtual Reality. The project group expected those, who have made an experience with these things to interact better and more experienced with the Leap Motion device.


Are you experienced in manipulating 3D models on your computer? *

○ No

○ Yes

Figure 9: Asking if the participant has experience in manipulating 3D models.

The thought behind asking this question was to see if participants, who are experienced in interacting with a 3D model on their computer with their computer mouse, would also be better in manipulating a 3D model with the Leap Motion Device.

3.3.4. Leap Motion Demonstration and explanation of the virtual environment

Before explaining how the user survey will be continued, the virtual environment, in which the participant of the survey will work, needs to be introduced and explained.

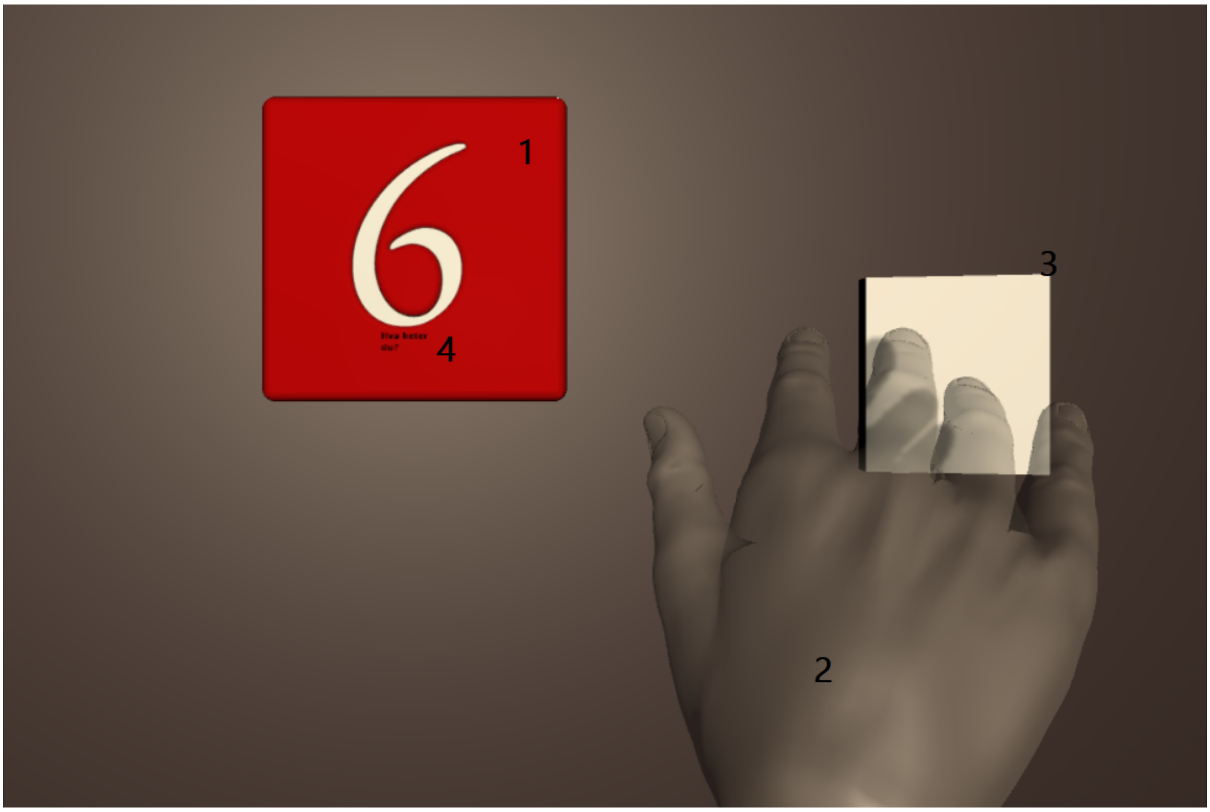


Figure 10: Virtual environment, in which the participant of the survey interacts.

This is the virtual environment every participant of the survey was working in. The following part will explain, what the numbers in the picture are referring to.

1. This is a 3D model of a dice. The participant of the survey will mostly work with the dice during the user survey. Two features were linked to the dice. It can be translated, rotated and scaled by using certain gestures.

2. A Hand appears in the virtual environment, if the participant of the survey is moving his or her hand above the Leap Motion device.

3. A button will appear, if the participant is moving his or her hand into the right part of the virtual environment. If one's hand is elsewhere, the button will disappear. The button resets the position, the rotation and the scale of the dice once pushed.

4. "Hva heter du?" is written in a small font under the number six of the dice. This phrase will be part of an upcoming task the participants of the survey are asked to solve.

The virtual environment as it can be seen in Fig x+9 was the default virtual environment, displayed every time the program was started.

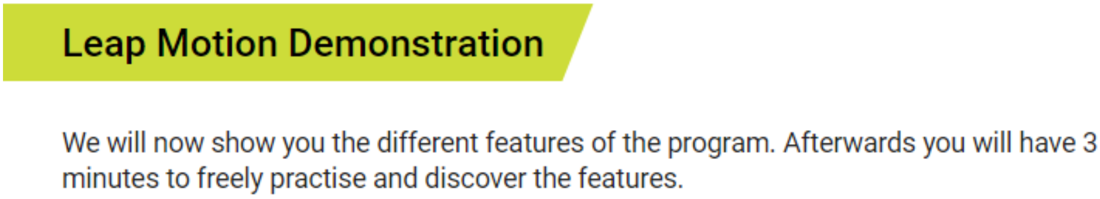


Figure 11: Introduction before the Leap Motion program was demonstrated.

Each participant followed a procedure. Features, such as translation, rotation, scaling (zooming) and resetting the dice, were presented. A script of how to demonstrate the features can be found in the appendix.

It was important, that no phrases were used, that might push the developed program towards a positive outcome.

3.3.5. User testing

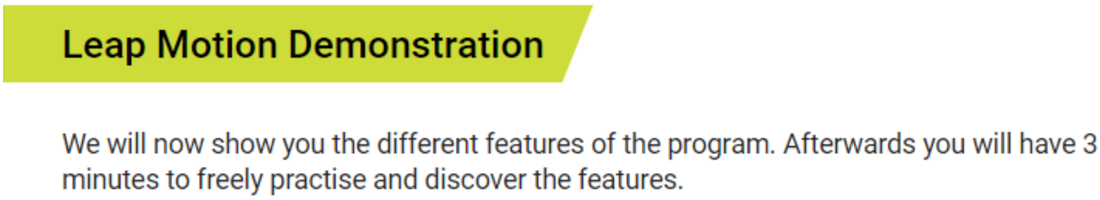


Figure 12: Introducing the upcoming tasks.

In order to analyze how well the Leap Motion program is working four tasks were created:

- A translation task
- A rotation task
- A zooming task
- A button task

The goal was to test every feature, the project group developed, in different short tasks. It needs to be mentioned, that the tasks were counterbalanced. The reason for that is, that the participants are gaining experience about how to use Leap Motion probably during the tasks. If you would have the same last task for every participant, the time participants would need to solve this task would always be lower than the time they would need, if they were doing this task for the first time. The Button Task was always asked after the Translation Task because it was required to know how to translate for solving the Button Task.

The following sequences were used:

Table y: Sequences used for the tasks

Rotation	Translation	Zoom
Translation	Zoom	Rotation
Zoom	Rotation	Translation

For every task, the time was taken and filled into a field beneath the description of the task.

3.3.6. Translation

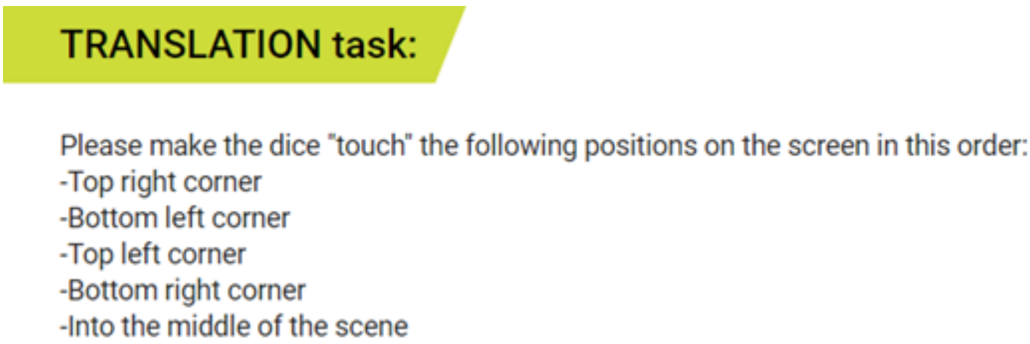


Figure 13: Explanation of the Translation Task

The goal of the translation task was to pinch with the fingers and be inside the dice, so the participant could grab it. After grabbing the dice, the dice should “touch” the corners of the screen in the sequence, that was mentioned in Fig x+11.

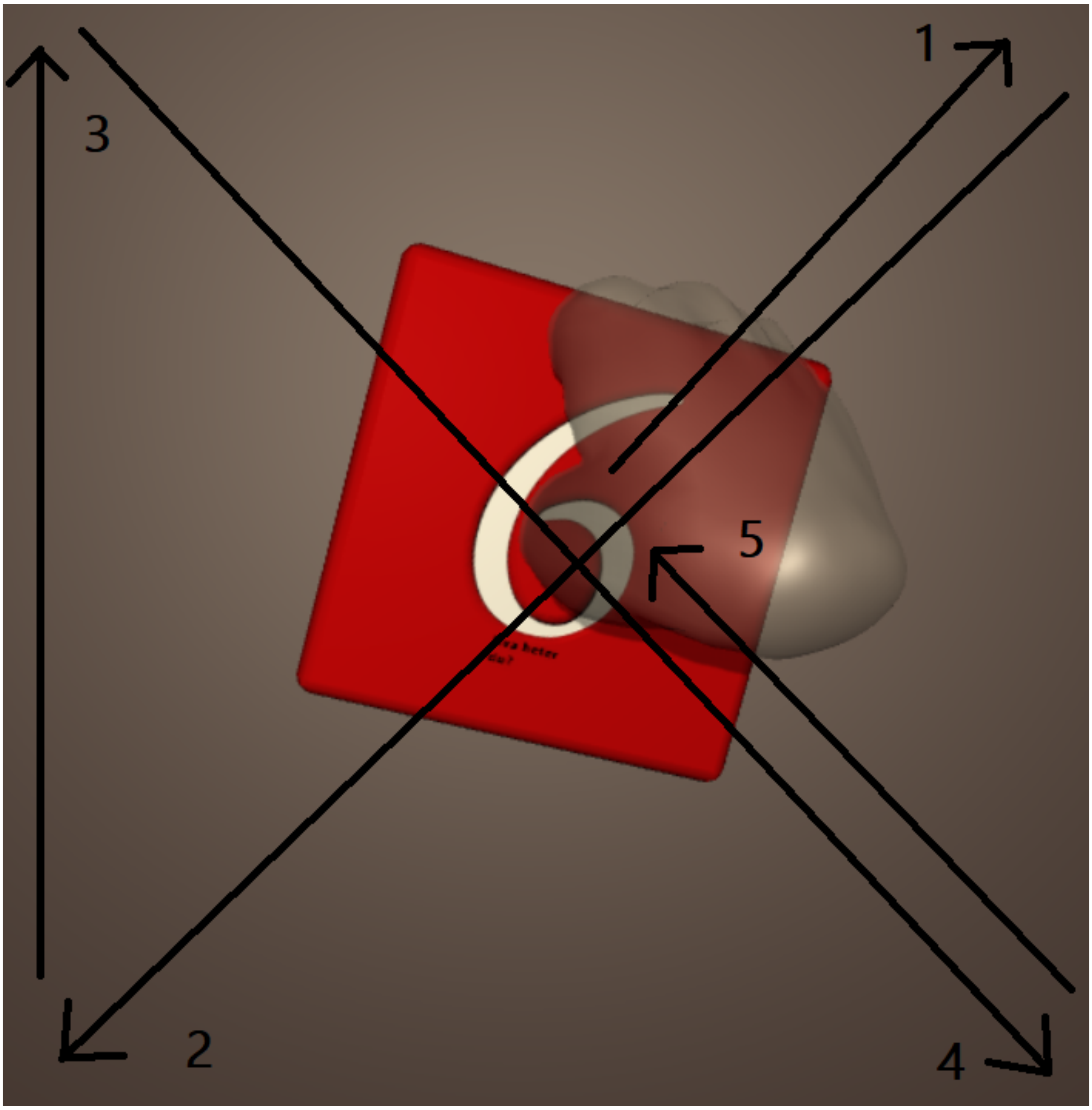


Figure 14: movement procedure

3.3.7. Rotation

ROTATION task:

Please rotate the cube into the following positions so we can see these numbers in this order:
-5
-4

Figure 15: Explanation of the rotation task

This task aimed to assess the understanding of the participant between pinching in the dice and not pinching. By not pinching in the dice and just having your hand in the model, the 3D model of the dice would only rotate with your hand and not move.

Figure 16: Rotation of the dice

3.3.8. Zooming

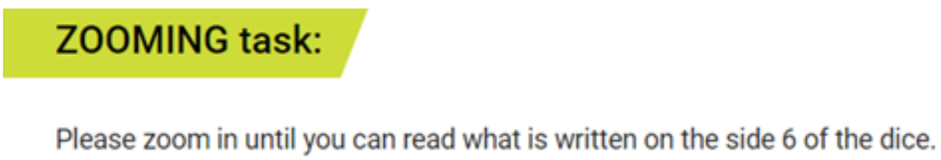


Figure 17: Explanation of the Zooming Task

The Zooming Task required participants to use both of their hands in order to change the scaling of the dice. The goal was to read the little written sentence “Hva heter du?”.

Figure 18: Dice after changing its scaling.

3.3.9. Button

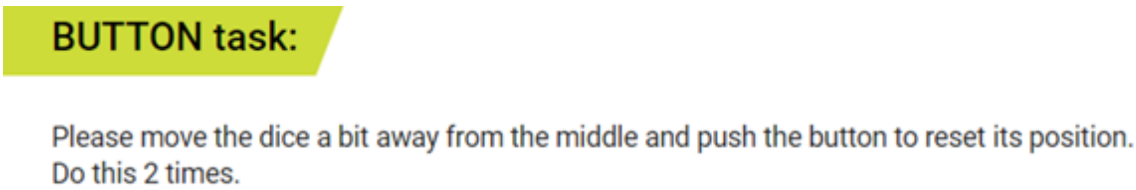


Figure 19: Explanation of the Button Task

For this task the pre-knowledge of translating an object in a 3D virtual space was required. The goal of this task was to see, if the participants could understand how deep the button is in the virtual environment and how swiftly they could move away the dice and press the button twice.

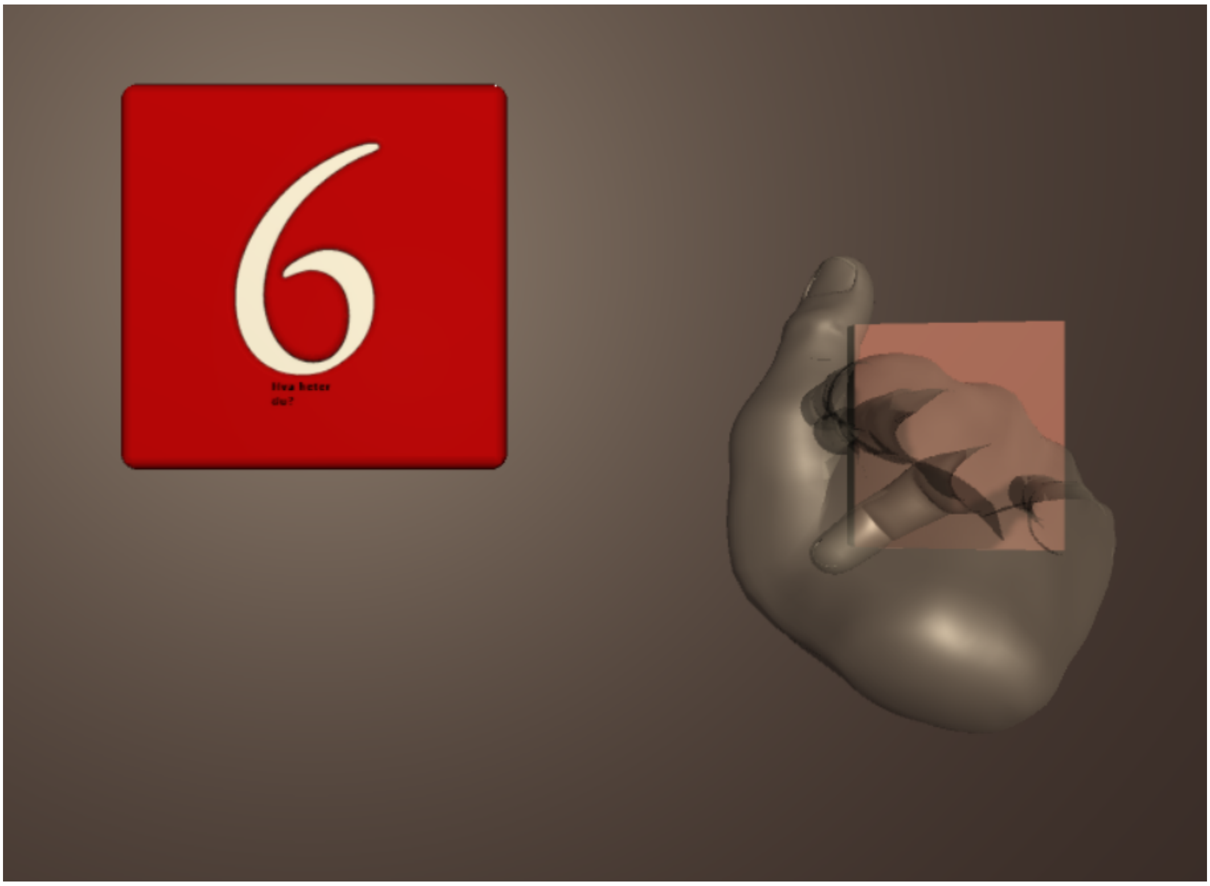


Figure 20: Pressing the button

3.3.10. Feedback

Leap Motion Survey:

In this part we are asking about your opinion. You will be able to answer with numbers on a scale from 1 to 5, with 1 as a sign of strong disagreement and 5 as a sign of strong agreement.

Figure 21: Explanation of the reviewing system

In the final part of the survey, the participant were asked about their honest opinions. As you can see in Fig x+19, the participants were able to answer on a scale from 1 to 5, one displaying a strong disagreement, while five represents a strong agreement toward the question.

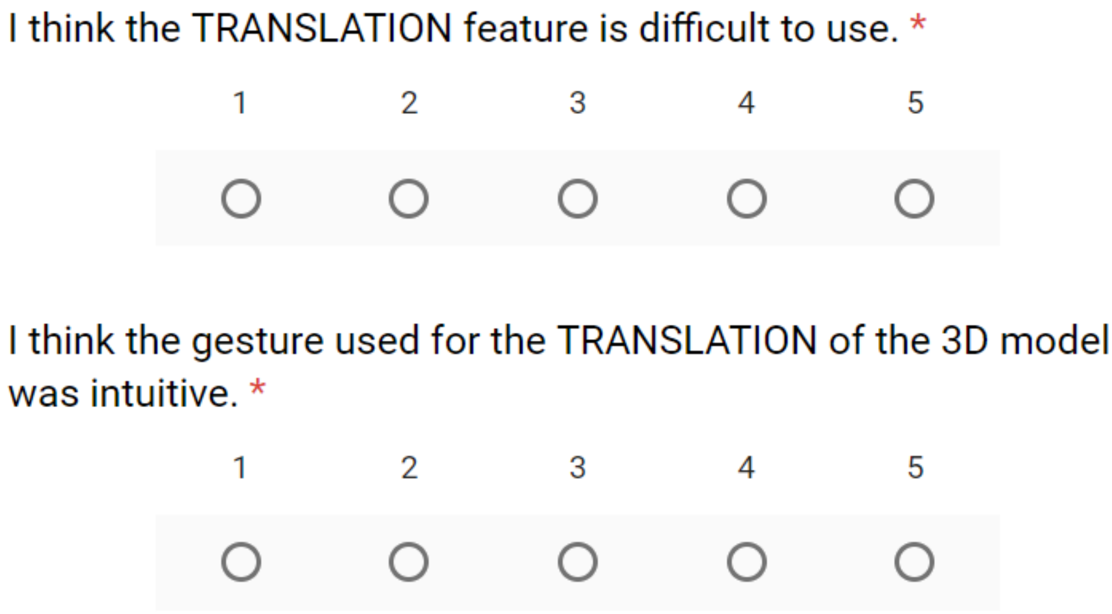


Figure 22: First two statements about the Translation feature.

There were always two statements given to one feature in the Leap Motion program. The first statement was asked with a negative adjective. The second statement was asked with a positive adjective. If the participant was satisfied about a feature and thought it would be easy to use, she or he had to give a 1 or a 2 in the first statement and a 4 or a 5 in statement two. The thought behind this system was to not let the participant fall into a rhythm, where she or he would always stick to the same numbers.

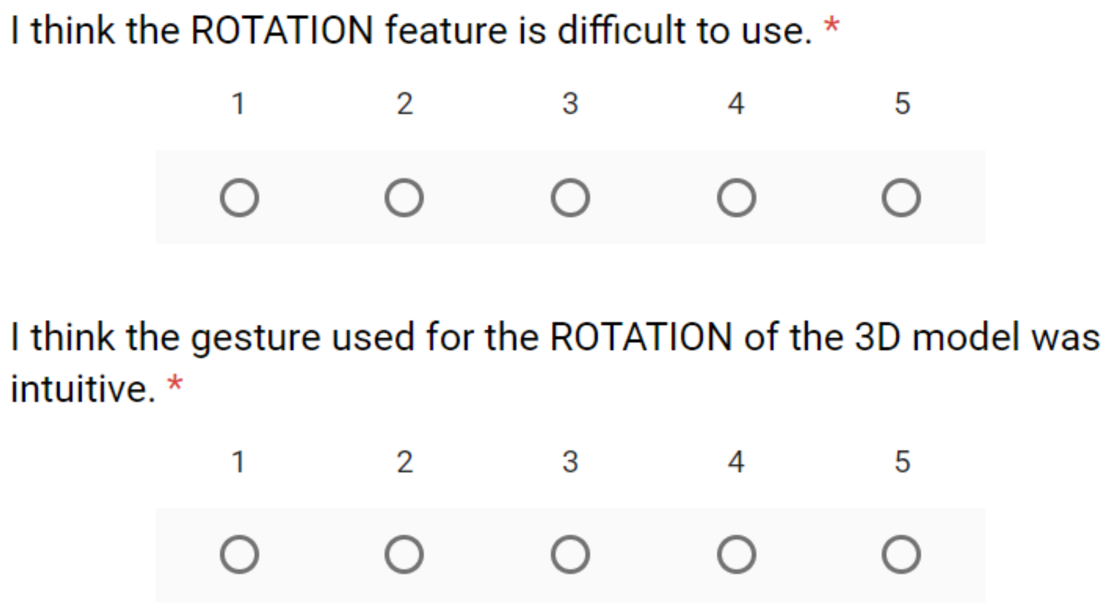


Figure 23: Statements about the Rotation feature

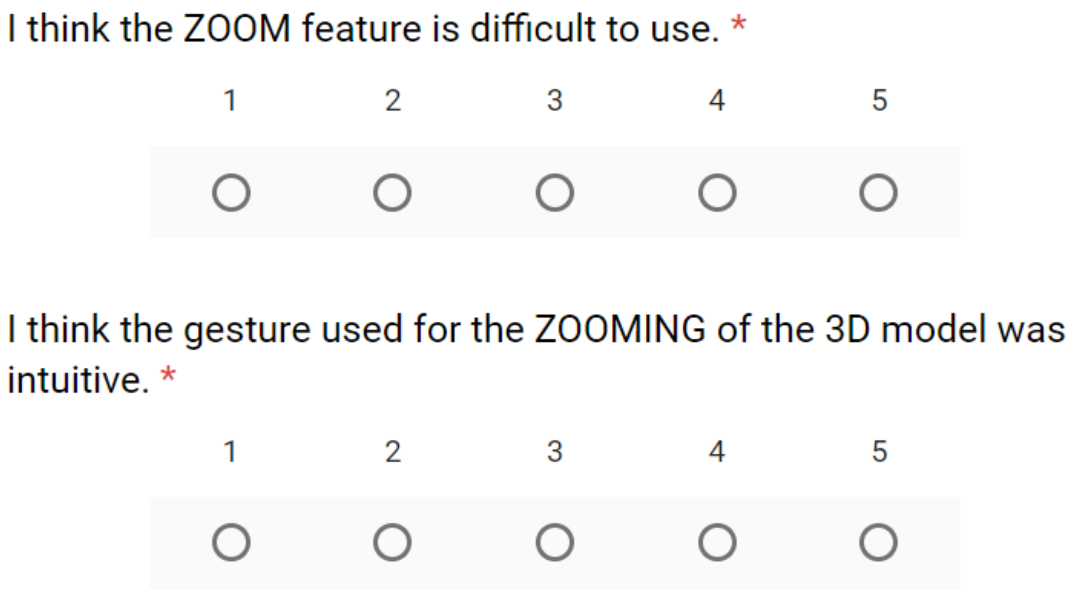


Figure 24: Statements about the Zooming feature

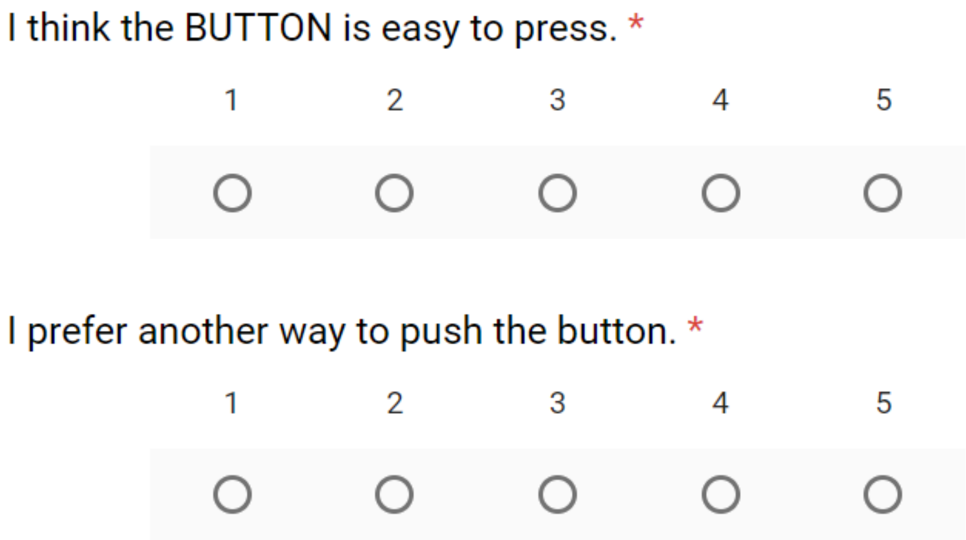
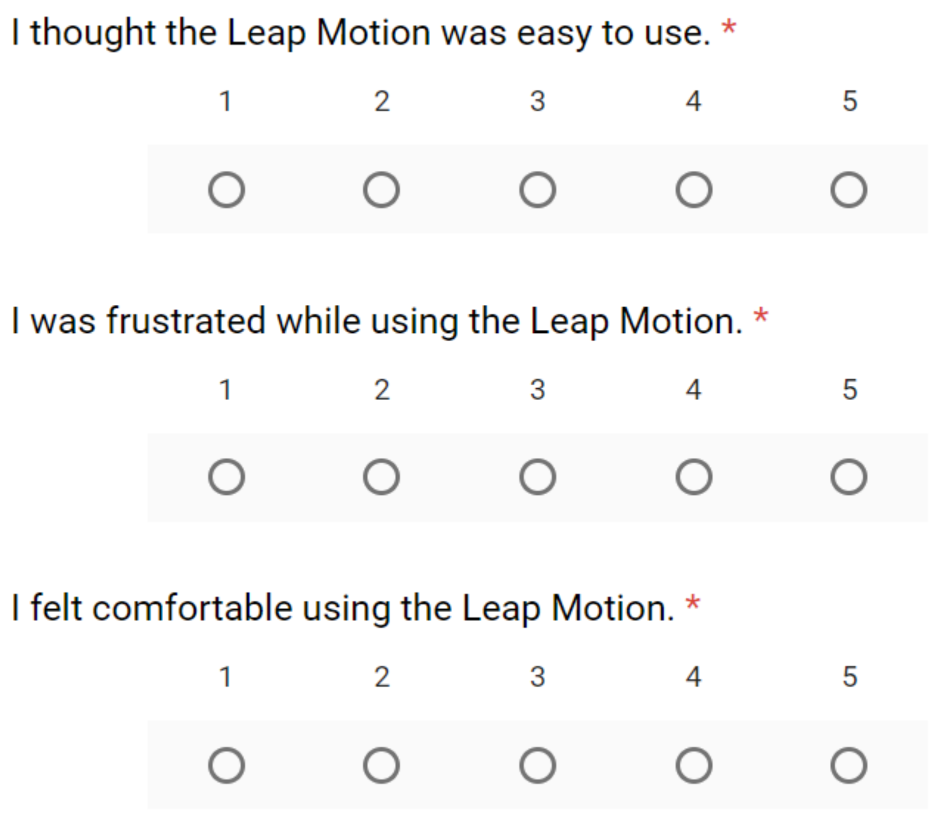


Figure 25: Statements about the Button feature

The statements about the Button feature differ compared to the prior statements. The thought is still the same. One statement with a positive adjective and one statement, which is formulated negative.

The following questions are about Leap Motion and how the participants felt using it.


I thought the Leap Motion was easy to use. *

1 2 3 4 5

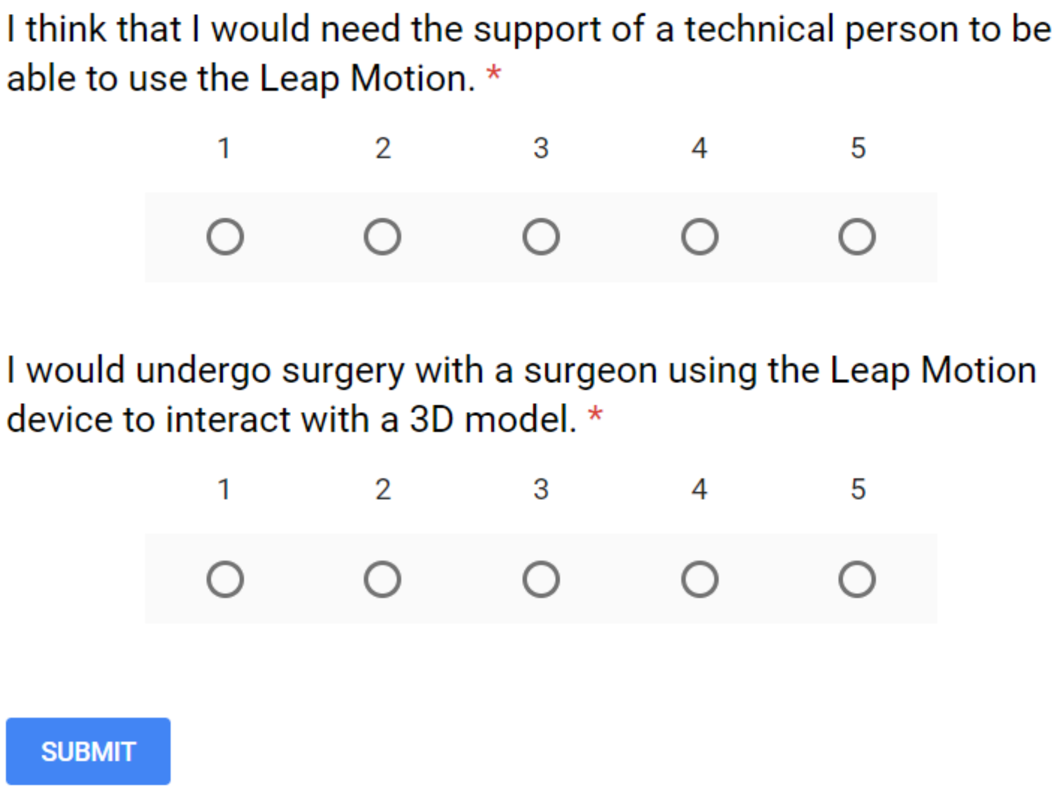
I was frustrated while using the Leap Motion. *

1 2 3 4 5

I felt comfortable using the Leap Motion. *

1 2 3 4 5

Figure 26: Statements about Leap Motion in general


I think that I would need the support of a technical person to be able to use the Leap Motion. *

1 2 3 4 5

I would undergo surgery with a surgeon using the Leap Motion device to interact with a 3D model. *

1 2 3 4 5

SUBMIT

Figure 27: Additional Statements and end of the survey by pressing the submit button.

4. Results

4.1. Program functionality

The final product contains various gestures and functionality which might differ from initial objectives.

4.1.1. Rotation

To rotate an object in any direction only one hand is required. The function will be executed upon entering the object with one hand. The collider of the object detects if a hand is touching or entering it and consequently sets a Boolean variable to true. After that, the rotation of the hand is assigned to the object's rotation. It is to be observed that no gesture is necessary to activate the rotation function. Thus, a reliable and comfortable method of rotating a 3D object is given.

4.1.2. Grab and move

In order to move an object, one has to perform a pinch gesture. No pre-installed gesture suited the demands of a responsive and reliable way to activate the translation function. Subsequently, the project's members developed their individual gesture for pinching. Whenever the thumb tip is closer to the other finger tips than a specific distance, a Boolean variable is set to true. Only pinching inside the object will execute the translation function. While moving the object, one can stop this function by releasing the pinch gesture. Grabbing and moving a 3D object with this technique does feel comfortable and intuitive, due to its natural resemblance in human society. Minor issues with the recognition of the pinch gesture still occur, because of the physical limitations the Leap Motion controller inherits. The device has two wide angle infrared cameras, which send the raw data to the microcontroller for further processing. If the pinch gesture is covered by the backside of the palm, the device has no direct line of sight of the fingers, thus the Leap Motion controller could misinterpret certain movements. For the most accurate and reliable execution of the pinch gesture, the palm of the hand should face the Leap Motion device.

4.1.3. Zoom

Enlarging an object was certainly the most complex function to implement. At first, the project group implemented a pinch to zoom gesture, which is also present on touchscreen devices. In theory, the object should enlarge upon entering it with one hand and expanding the distance between the thumb and the index finger. Scaling it down, one has to minimize the distance between these two fingers. If scaled down, the hand illustrates a pinch, which would interfere with the grab and move function. Thus, an alternative method for scaling an object was implemented. Presently, two hands are required to execute this function. Pinching both hands inside the object and expanding the space of the hands will scale the object in correlation to the distance of the hands. Therefore, a more reliable method of scaling an object is given.

4.2. Structure of the code

A major part is managed by *Unity* and the Leap Motion API. Therefore, the structure of the code is straightforward and adaptable.

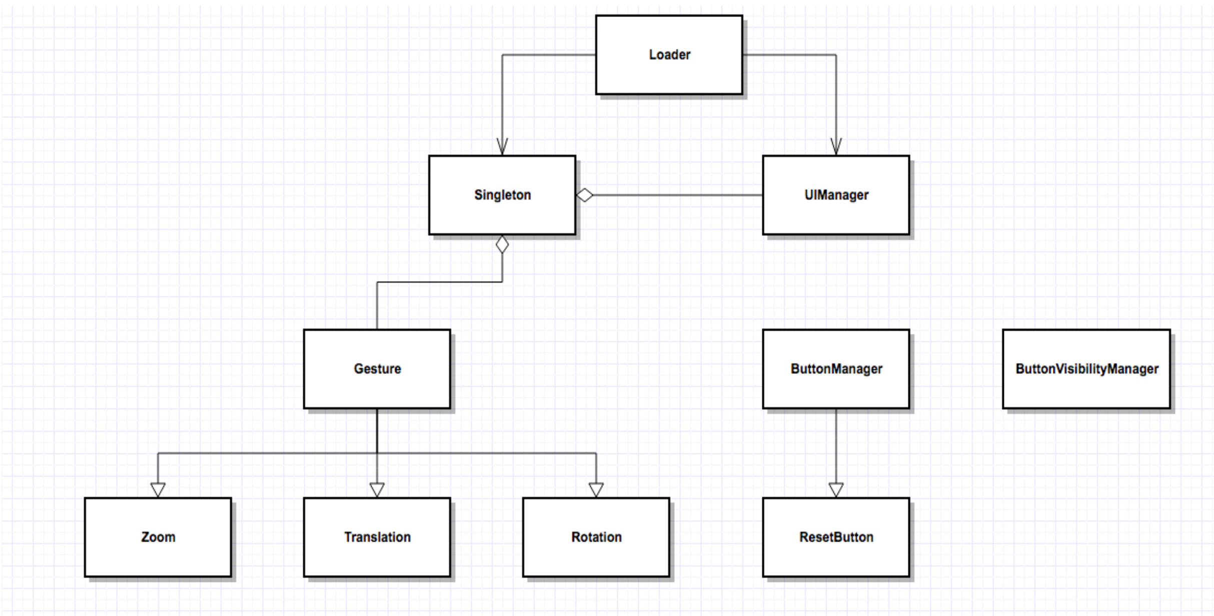


Figure 28: Object Diagram of the Application

4.2.1. Classes

Loader: Attached to a GameObject, it is the script that loads the UIManager and thus the Singleton.

Singleton: It is a design pattern. A class that can be instantiated only once and can be accessed from every other script inside the program. It contains the UIManager, the organ GameObject and its initial state, and a gesture list. This class's purpose is to contain the main information needed to be accessed from any other script. Furthermore, it is initializing the gesture list and the organ initial state.

UIManager: As it name is suggests, it manages the User Interface. At this moment, it displays the feedback icons, which represent the activated feature.

Gesture: This class is a parent class for every gesture that will be implemented. It contains the main specification each gesture shares.

Rotation, Translation, Zoom: These classes contain the gestures and execute features. They are associated with the organ GameObject as components.

ButtonManager: This class handles the behavior of a button as it is a 3D element in this application. It manages its movement and calls an activation method if the button is pushed.

ResetButton: This class inherits from the ButtonManager to share its behavior. The Activation method calls the ResetOrgan method of the Singleton to reset the organ to its initial state.

ButtonVisibilityManager: This class is associated with the parent object of the moving button. This parent has a collider to detect if the hand is in front of the button. When the hand enters the collider, the button appears and it can be pushed. The button disappears if the hand exits the collider.

4.3. Results of the survey

In this part the findings and results of the user survey will be presented.

In the upcoming parts the term average will be used. This value is calculated like this:

Average Time:

$$\bar{x} = \sum_{i}^{n} x_i * \frac{1}{n}$$

$\bar{x}$ is the average time taken to perform a certain task by all participants.

x_i is the time taken to perform a certain task by one participant.

n is the number of participants taking part in the user survey.

4.3.1. General Information

The project group wants to give a brief overview over the profile of the people, who participated in the user survey. 21 people participated in the user survey.

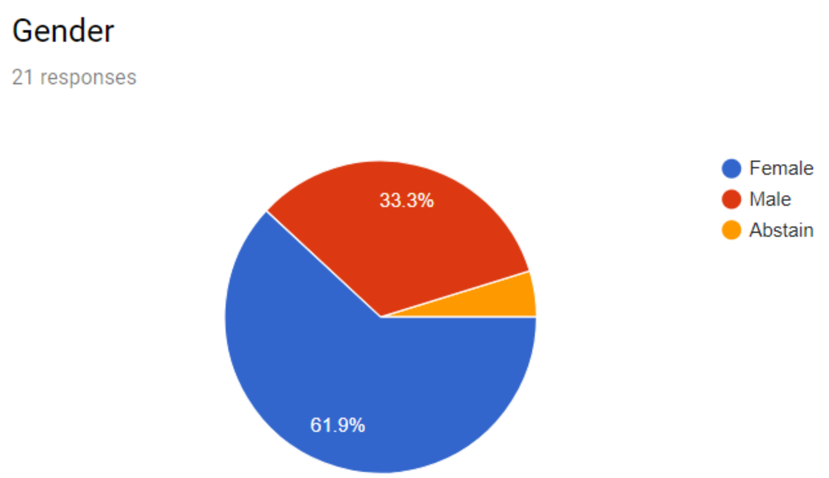


Figure 29: Gender demographic of the participants

7 participants were male

13 participants were female

1 participant did not want to give information about its gender

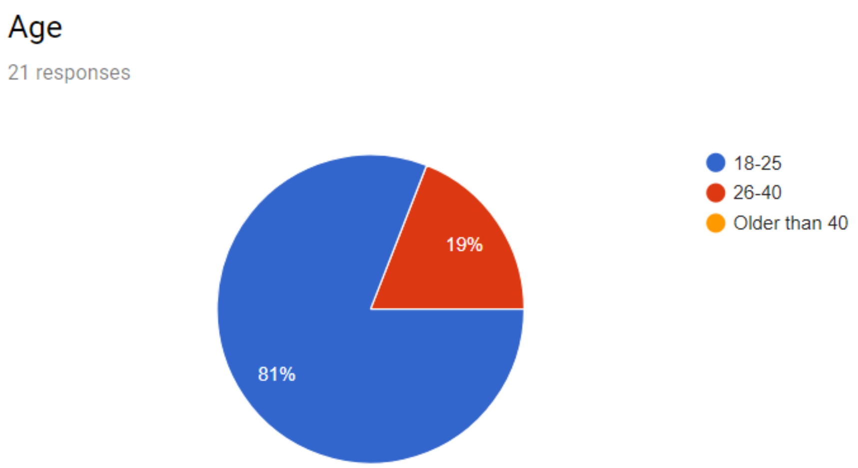


Figure 30: Age demographic of the participants

17 participants were between 18 and 25 years old

4 participants were between 26 and 40 years old

0 participants were older than 40

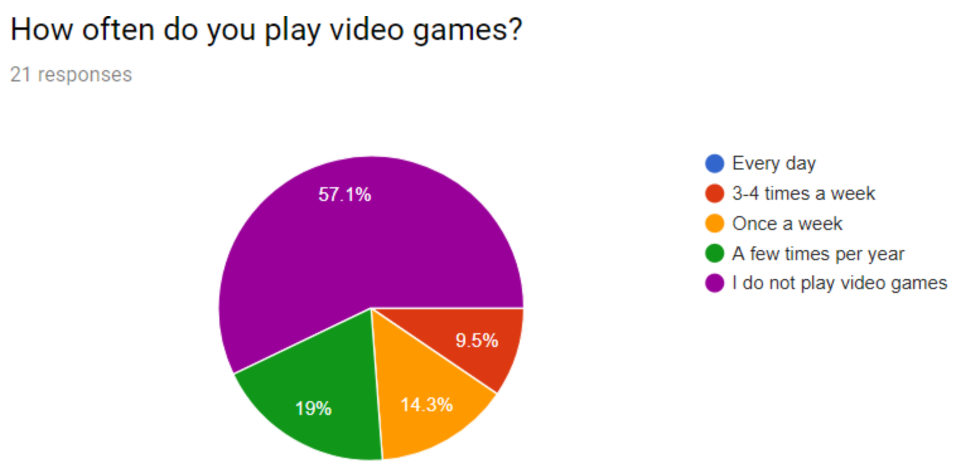


Figure 31: Frequency of the participants playing video games

0 participants were playing video games every day

2 participants were playing video games 3-4 times a week

3 participants were playing video games once a week

4 participants were playing video games a few times per year

12 participants are not playing video games at all

If you usually play video games. What are their names?

5 responses

Skyrim
Battlefield 1
call of duty
Mario Kart, The legend of Zelda
Crash Bandicoot

Figure 32: List of video games, that are played by the participants, who play video games

If you play video games, are they 2D, 3D or both?

7 responses

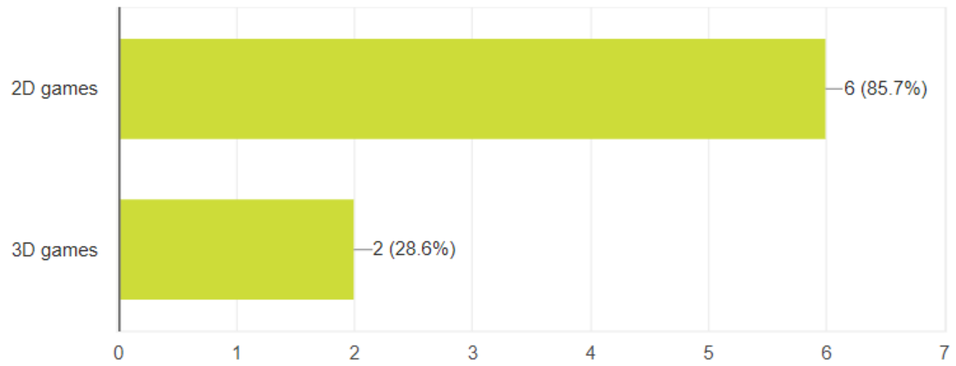


Figure 33: Amount of people playing 2D or 3D video games

Have you ever worked with Leap Motion or in Virtual Reality?

21 responses

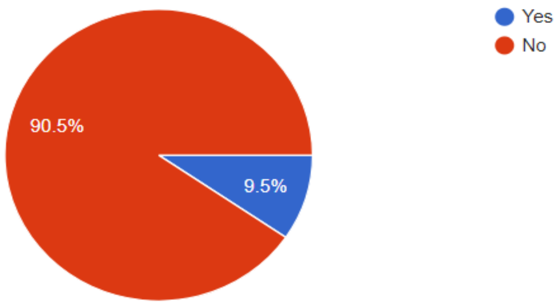


Figure 34: experience with Leap Motion or Virtual Reality.

19 participants have never worked with Leap Motion or Virtual Reality

2 participants have worked with Leap Motion or Virtual Reality

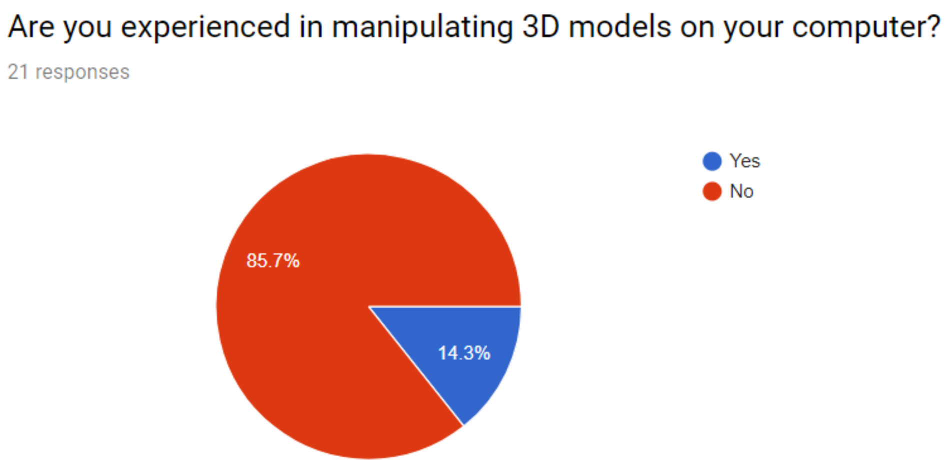


Figure 35: experience in manipulating 3D objects of participants.

3 participants were experienced in manipulating 3D models on their computer

18 participants were not experienced in manipulating 3D models on their computer

4.3.2. Results

The following part will be about the taken time to solve each task, the participants' opinion about the features and a brief analysis on how a task was solved.

Before assessing the gathered data, a few abnormalities concerning the execution of the survey tasks need to be mentioned:

Nearly every participant experienced the Leap Motion for the first time. By having three minutes of practice, participants could experience the strengths and weaknesses of the device, but it was not enough time to experience how to deal with the "design problems", that the Leap Motion device has.

The detection area of the Leap Motion Device is limited, therefore it was hard for some participants to find the right position, where they could work with the Leap Motion device.

Some participants thought one could accelerate the dice by tossing it away. The survey should have asked, if the participant is left or right handed, so the positioning of the Leap Motion device could have been adapted. The majority of participants were missing a physical feedback upon touching the dice or pressing the button. By taking the time, the participant needed to solve a certain task, time pressure was applied to participants.

4.3.2.1. Translation

The following figure will show how much time the participants needed to solve the translation task.

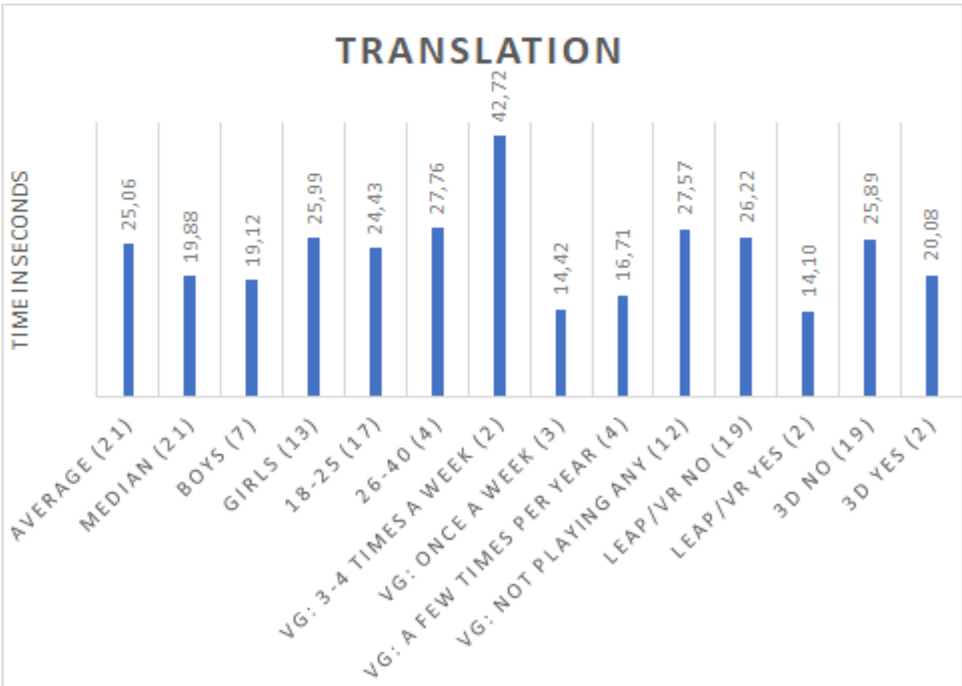


Figure 36: Average times taken for the Translation task

The participants answers, to the statements about the translation feature, are shown in the upcoming part.

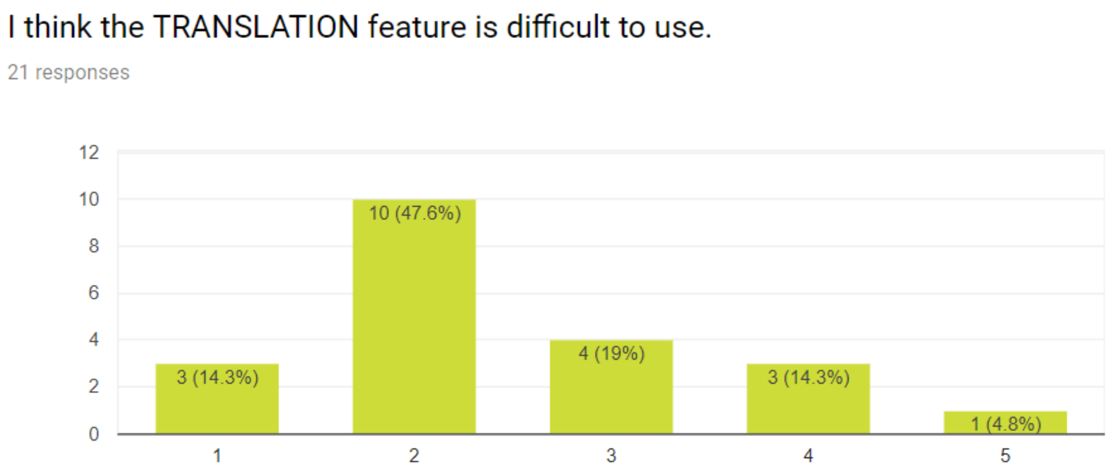


Figure 37: Answers to statement one of user survey

13 out of 21 people disagreed with the statement, that the translation feature is difficult to use.

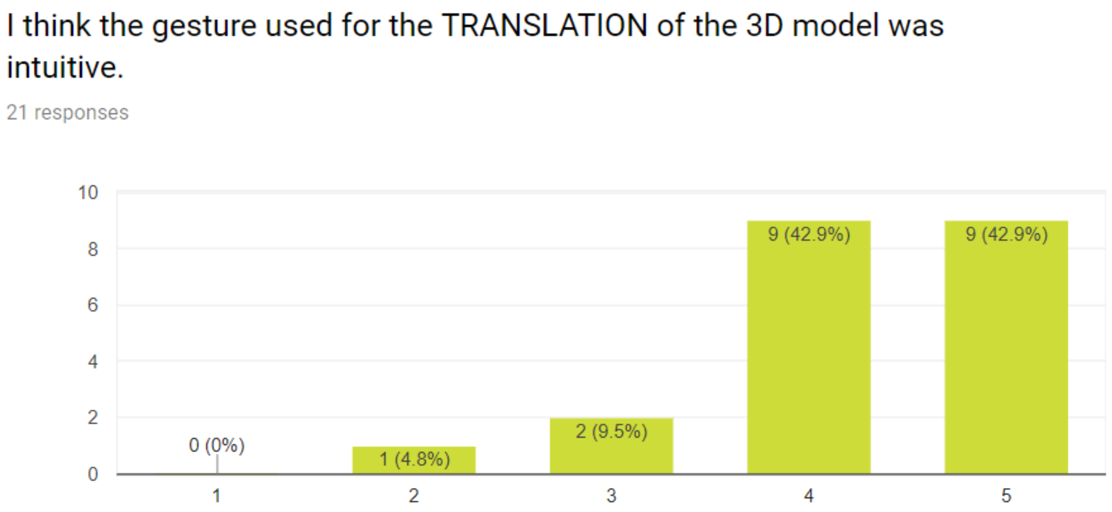


Figure 38: Answers to statement two of user survey

18 out of 21 participants agreed with this statement, which suggests, that the participants were satisfied with the gesture, chosen for translating a 3D object.

Abnormalities during the translation task

Some did not know what the word "Translation" meant. A few participants lost the dice because they were moving their hand too fast or leaving the detection area of the Leap

Motion device by trying to touch the corners. Some participants did not pinch in the dice, but made a fist to translate it. Most of the times the translation still worked

4.3.2.2. Rotation

The following figure will show how much time the participants needed to solve the rotation task.

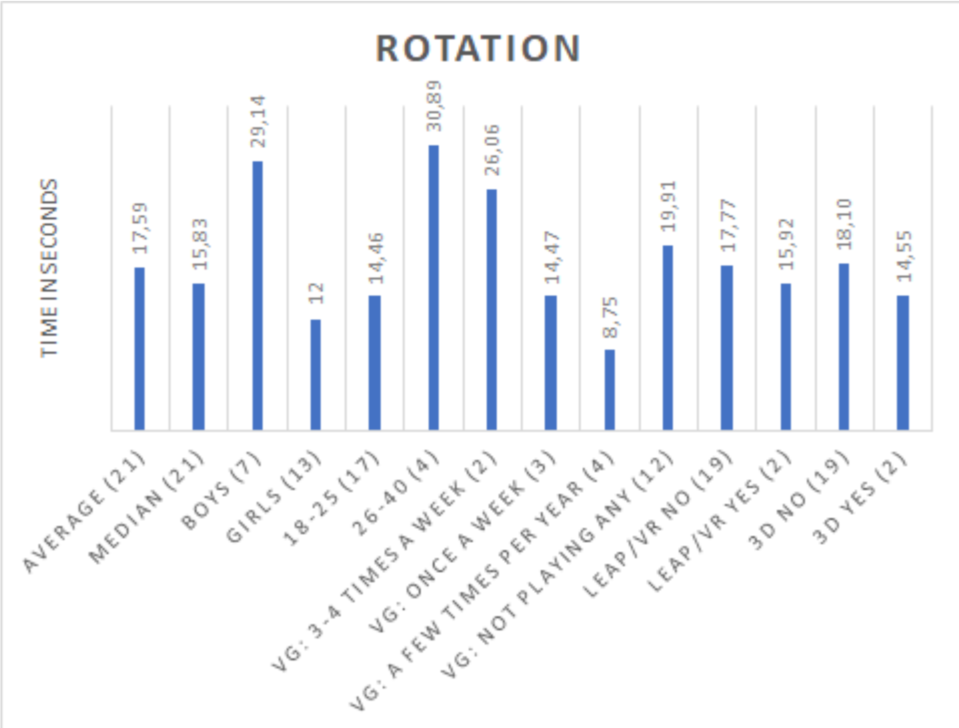


Figure 39: Average times taken for the rotation task

The participants answers, to the statements about the rotation feature, are shown in the upcoming part.

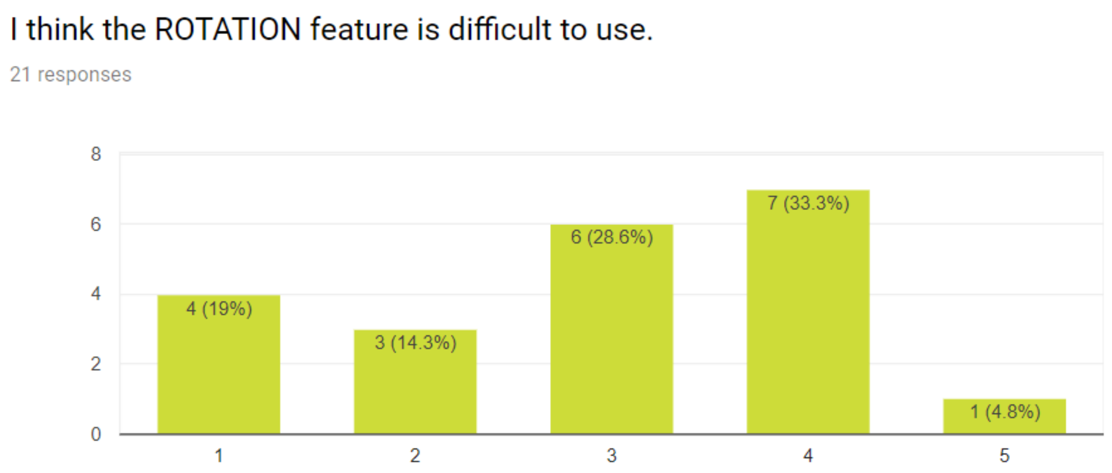


Figure 40: Answers to rotation feature statement

Seven participants disagreed with the statement, that the rotation feature is too difficult to use. Eight participants agreed with that statement. By observing the participants performing the task, the project group found out, that the gestures for the rotation and the translation feature might be too similar. Since one can rotate the object with the translation feature too.

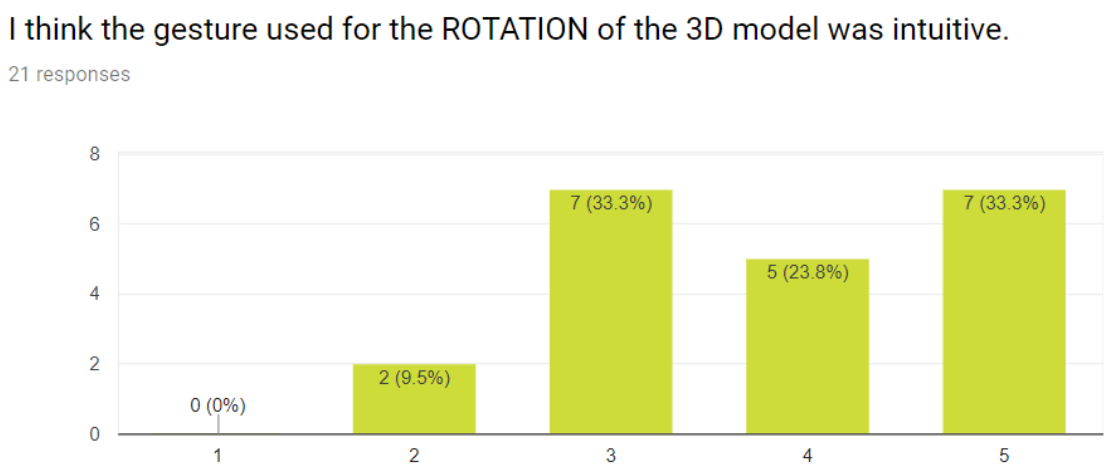


Figure 41: Answers to rotation gesture statement

Although the gesture used for the rotation might be similar to the gesture used for the translation, the majority of the participants were satisfied with the gesture chosen for the rotation feature.

Abnormalities during the rotation task

Participants pinched in the dice, what means, that they grabbed the dice to rotate. They were not supposed to grab the dice. The participants were not interrupted, and they could solve the task in this way as well. A few participants had the issue, that the dice moved away by mistake, while they tried to rotate it.

4.3.2.3. Zooming

The following figure will show how much time the participants needed to solve the zooming task.

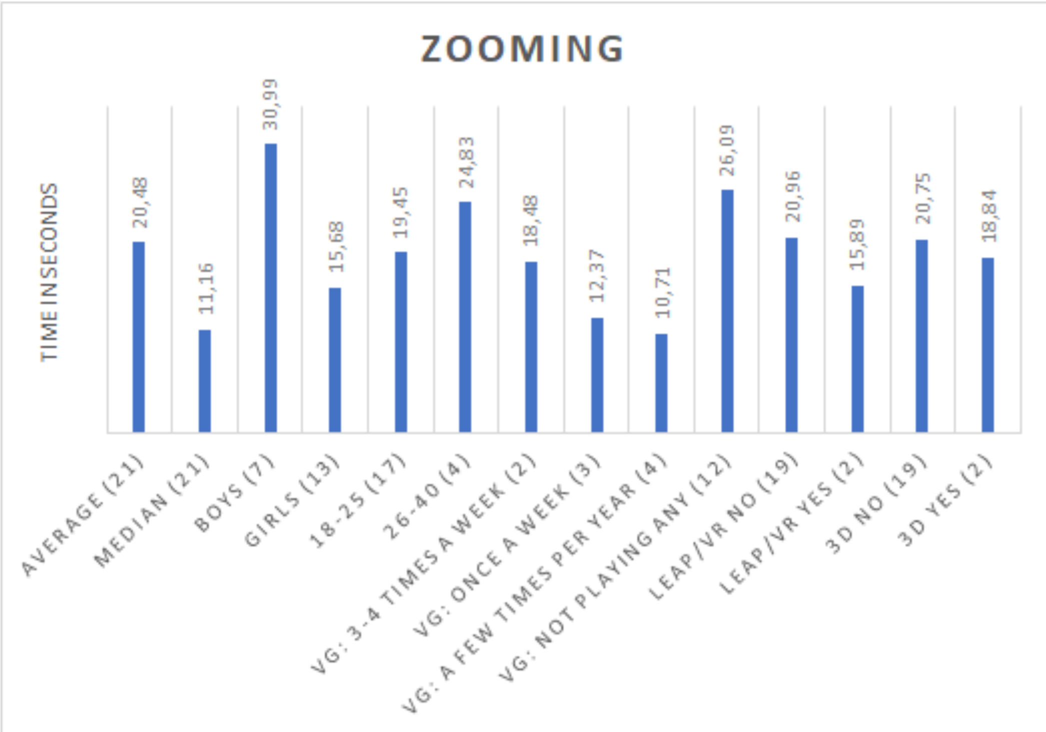


Figure 42: Average times taken for the Zooming task

The participants answers, to the statements about the zooming feature, are shown in the upcoming part.

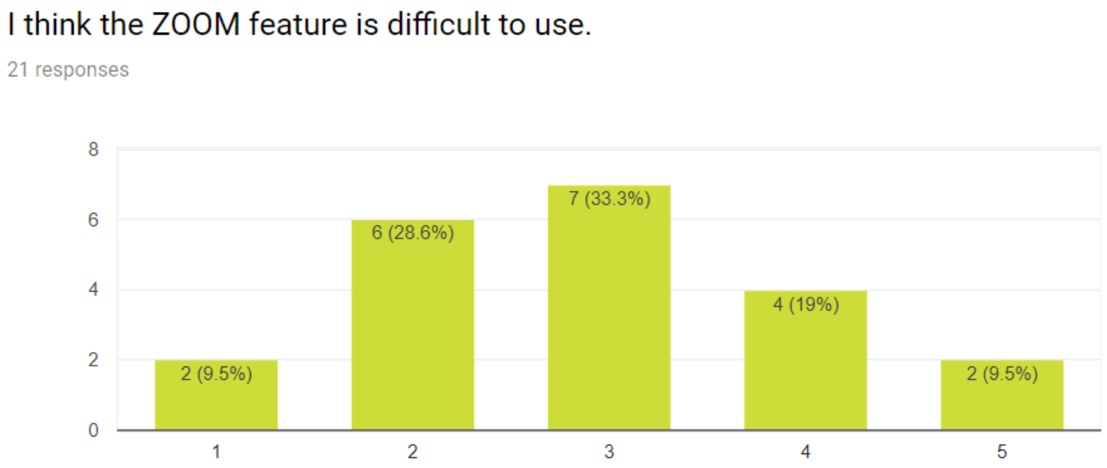


Figure 43: Answers to zoom feature statement

The project group could see, that the zooming feature is difficult to use for nearly half the participants.

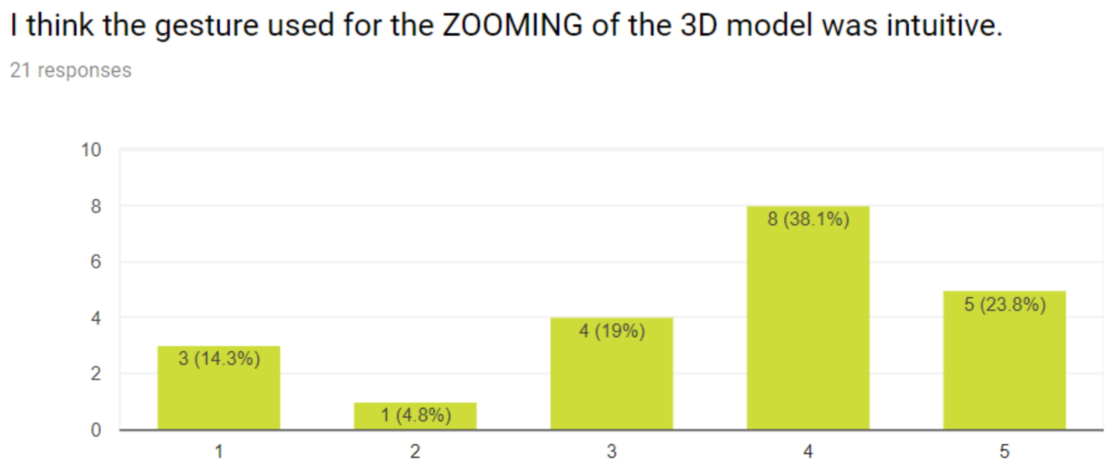


Figure 44: Answers to zooming gesture statement

The chosen gesture seems to be accepted by the majority of participants. It is in comparison to the other gestures the only one, which requires two hands.

Abnormalities during the Zooming Task

Occasionally the zooming task was solved swift, because the dice glitched out and changed its scale to the right scale, in which the participants could read what was written on the dice. When the dice's scale was increased too much, it filled the whole scenery. In this case it was hard to decrease the scale of the dice again and sometimes the program had to be restarted by one member of the project group.

4.3.2.4. Button

The following figure will show how much time the participants needed to solve the button task.

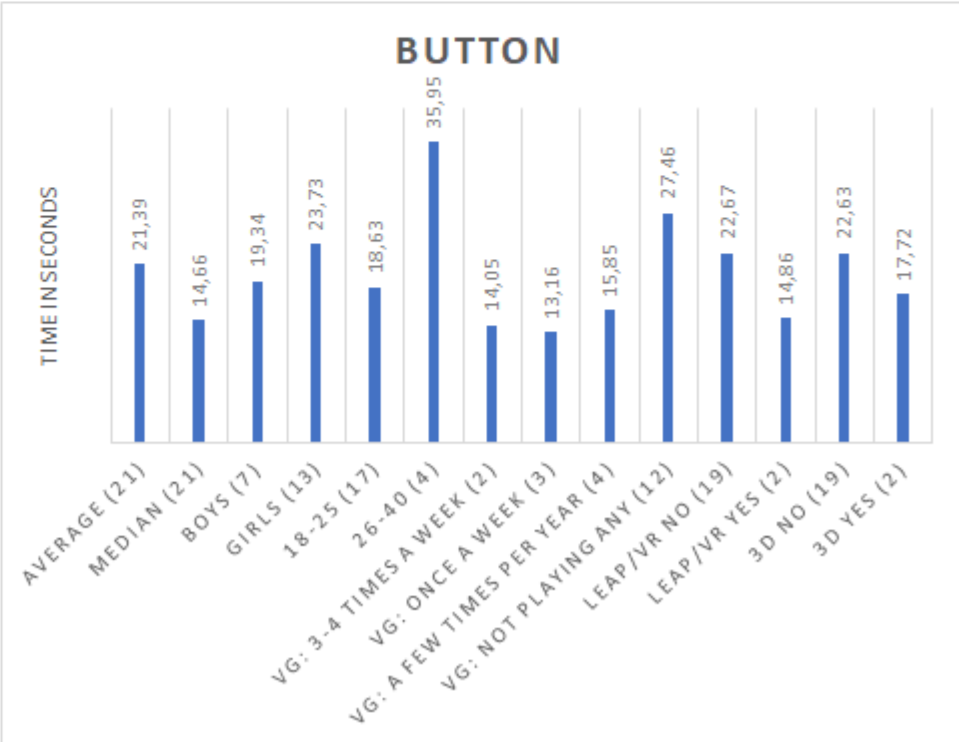


Figure 45: Average times taken for the Zooming task

The participants answers, to the statements about the button, are shown in the upcoming part.

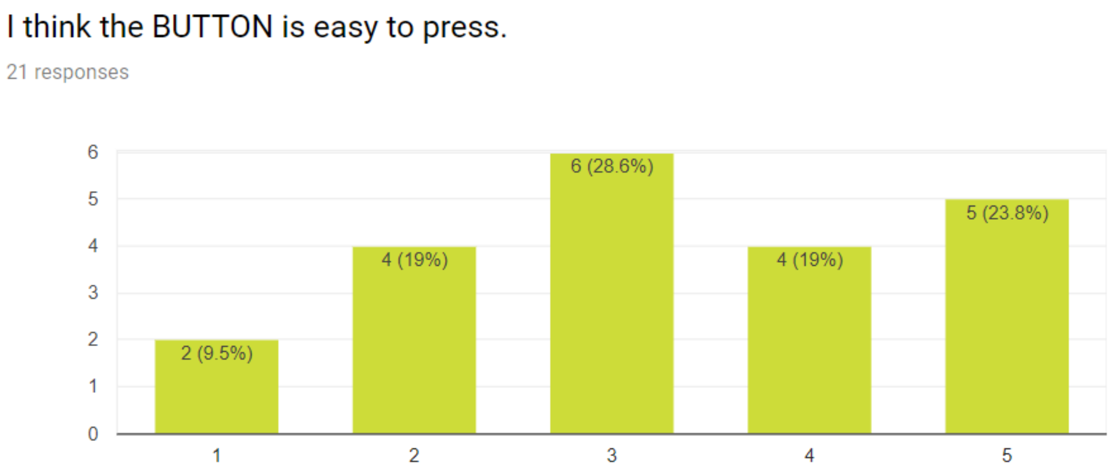


Figure 46: Answers to button ease of use statement

Most of the participants thought, that the button was easy to press.

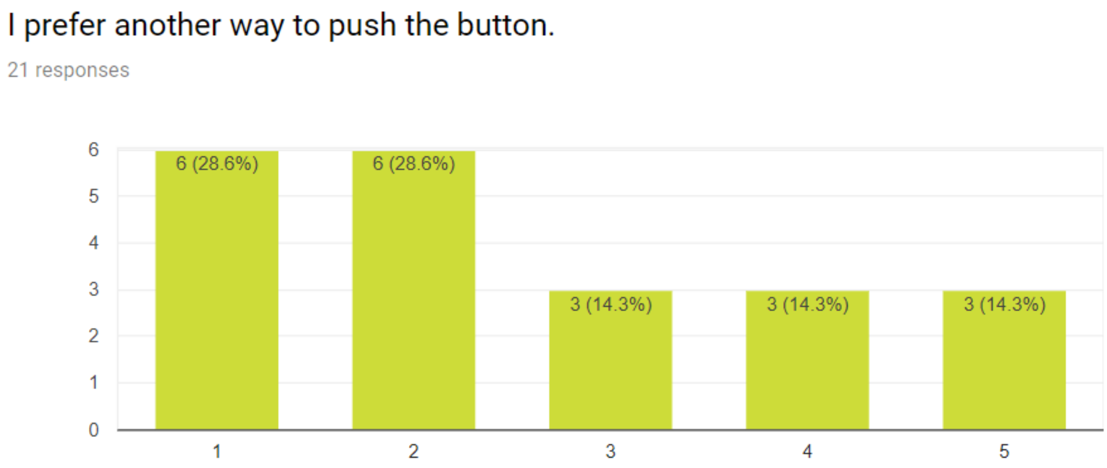


Figure 47: Answers to alternative button statement

The chosen way of pushing the button seems fine as well.

Abnormalities during the button task

A great number of participants did not have a feeling for the deepness of the scenery. Therefore, they tried to push the button in a place, where it was not. People tried to push the button from the side. The button got stuck sometimes.

4.3.2.5. Additional statements

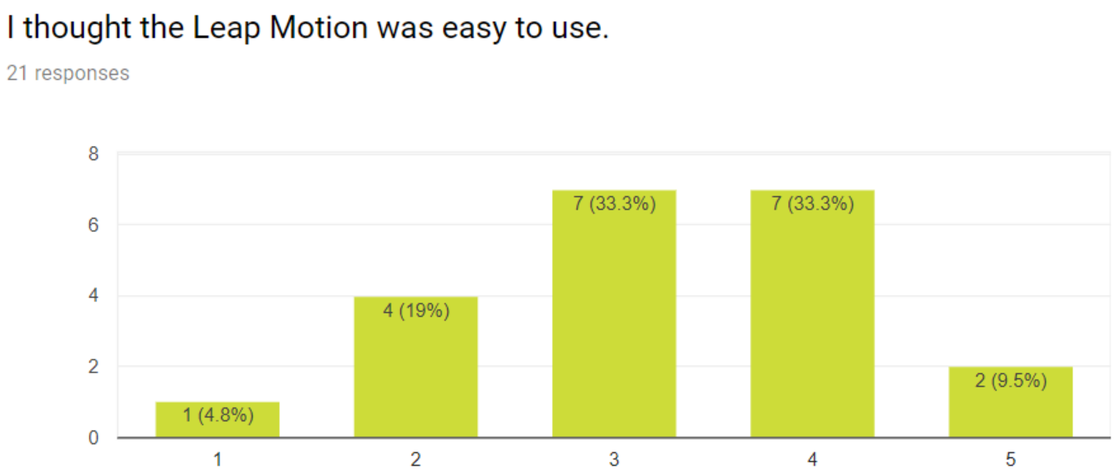


Figure 48: Answers to ease of use of Leap Motion statement

The majority of the participants were unsure or tended to slightly agree, that Leap Motion is easy to use. That is understandable because it seems, that Leap Motion in combination with the written program requires some practice to manipulate a 3D model.

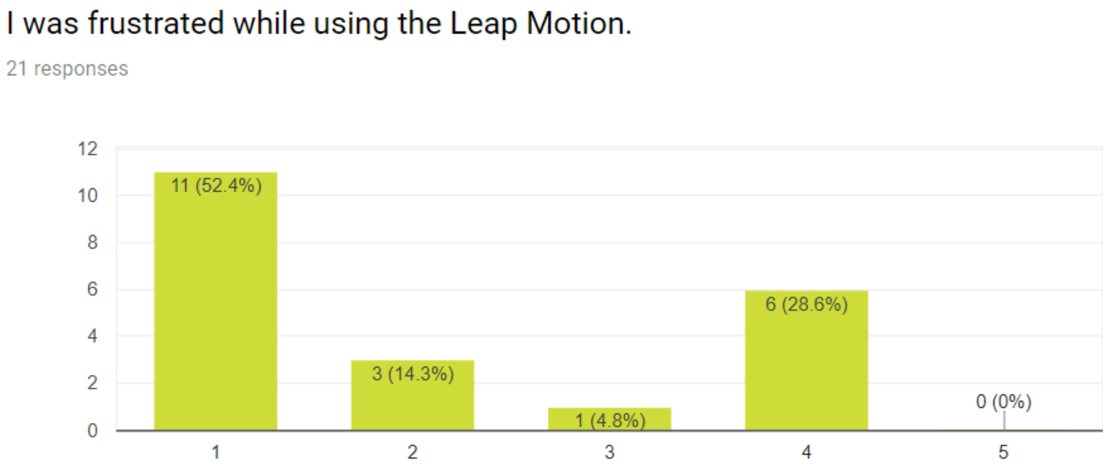


Figure 49: Answers to Leap Motion frustration statement

Although Leap Motion requires some experience, most of the participants were not frustrated by using the Leap Motion. The goal of the survey was not to show a fun and innovative technology, although a lot of participants stated, that they had fun doing the survey and that Leap Motion is an interesting technology.

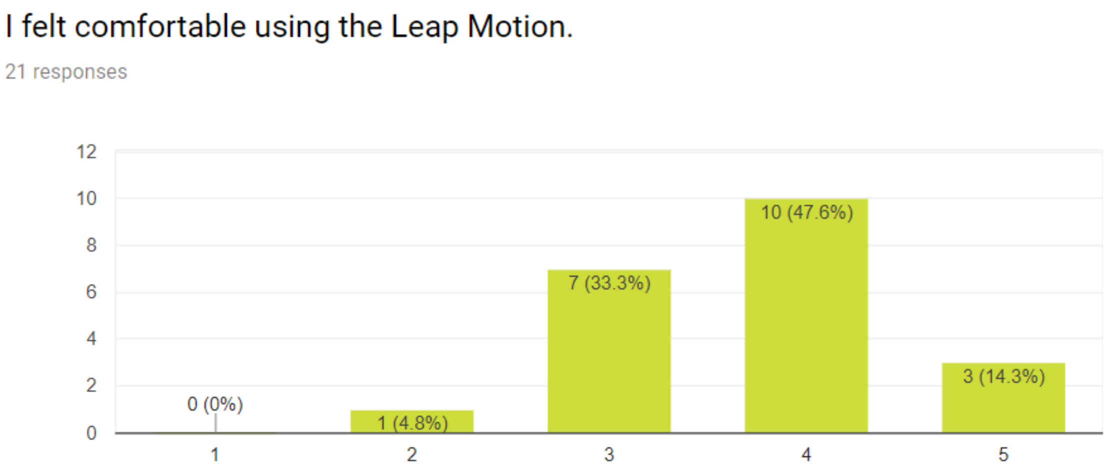


Figure 50: Answers to comfortable use of Leap Motion statement

Only one person felt slightly uncomfortable using Leap Motion.

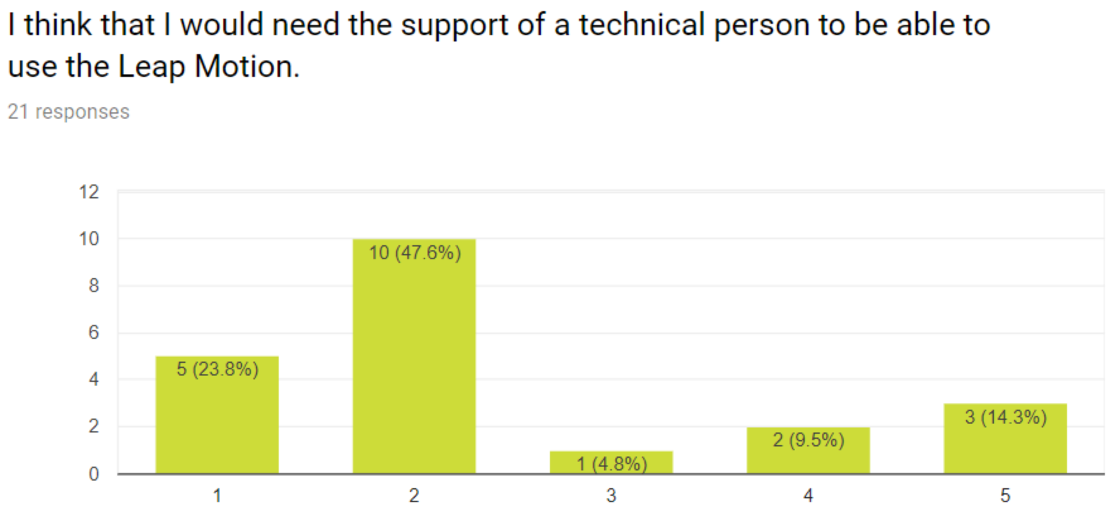


Figure 51: Answers to support statement

15 participants said, that they would not need the help of a technician to be able to use Leap Motion. That shows the project group, that Leap Motion in combination with the written program is intuitive enough in its current state.

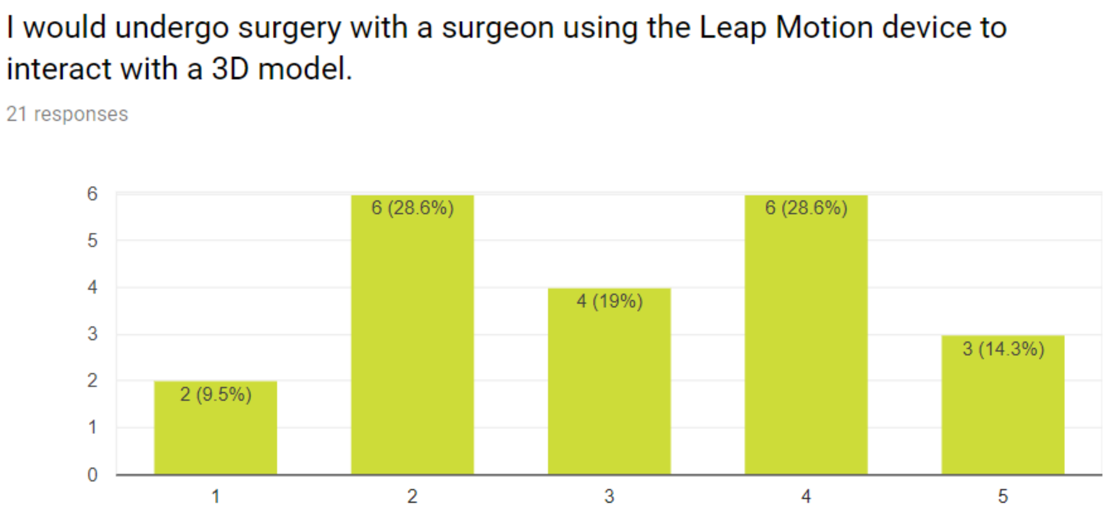


Figure 52: Answers to surgery statement

Nearly every participant mentioned, that this is the statement, which is the hardest to answer. The reason for that might be, that the participants saw, that the program was intuitive and good working but yet not finished enough to use it during a surgery. Some people thought, that a surgeon would use Leap Motion to control a machine, which would perform surgery on them. In the end nine people tend to go under surgery, while a surgeon is using Leap Motion and 8 tend to not go under surgery with a surgeon using a technology like this.

5. Discussions

5.1. Survey Analysis

The user survey was a necessity. Its aim was to see how the participants interact with Leap Motion in combination with the developed program and their opinions about it. The gathered data was vital for assessing and improving the program. In retrospect, certain parts of the user survey should have been changed or rethought. The following paragraph includes thoughts the project group had during analyzing the collected data.

A number of 21 participants seems sufficient, although the amount should have been higher in some cases. The people who already had experience with Leap Motion or experience in manipulation of 3D models were faster in every task than people without experience in any of these fields. Since three participants were experienced in manipulation of 3D models and two participants had experience with Leap Motion, the project group cannot make a statistically proofed statement, that says that these people are definitely faster than people without experience in any of these fields. The project group can state, that people, who have experience in manipulation of 3D models or experience in working with Leap Motion tend to be faster than people without any experience in these fields.

Since some participants solved tasks with mere luck (glitching out of the dice) and some participants had “bad luck” trying to solve the tasks, it is obsolete to do a standard deviation of the average calculation. A solution to this issue could have been to make the participants solve the tasks more than one time. A table with the standard deviations can still be found in the appendix. The group decided, that it is more useful to use the Median instead.

The taken time of tasks was difficult to measure. In some cases, the time should not have been used to calculate an average because it was a time influenced by luck or bad luck. That is also the reason, why calculating a median was important. The project group would even go further and say that one can make better statement based on the median than on the average. It was already mentioned, that doing a task several times could have fixed this issue. A side effect of this solution would be, that the time of the survey would have increased significantly.

5.2. Feature Analysis

All project members developed the program, thus they had sufficient practice with the Leap Motion controller to manipulate 3D objects throughout the semester. Most Interviewees, who participated in the user survey, were not familiar using this kind of input device in a virtual 3D space. Therefore, the project team discovered critical issues of the program from these interviewees, which were not obvious for the team.

5.2.1. Grab and move

According to the user survey, the majority of the interviewees found that the grab and move feature (translation) was not difficult to use, since the gesture used for translating the 3D object was intuitive for more than 85 % interviewees. There were several complaints concerning the missing physical feedback, when touching the dice by the participants. Given this circumstance, it is safe to say, that nearly all interviewees are accustomed to receiving physical feedback upon touching a touchscreen or other objects. From a clinical perspective, this argument has little or no validity. The project's target group, which are surgeons, can use the software in combination with the Leap Motion device directly with no help of an assistant or nurse, due to its sterility.

5.2.2. Rotation

As stated in the results of the user survey, the rotation feature was for at least seven participants difficult to use. The project team intentionally did not tell the interviewees how to execute these features, in order to see if it was possible to swiftly learn the gestures used to trigger the features. The grab and move feature also enables one to rotate an object. Due to this pre-knowledge, several interviewees successfully accomplished the rotation task without using the rotation feature. Considering this, it is essential to explain the project's target group how to execute certain features and gestures. This feature requires no gesture, thus it was for the majority of the participants intuitive. As reported by the findings of the user survey, few interviewees moved the dice while trying to execute the rotation feature.

This is because their hands were not flattened out, thus triggering a possible a pinch, which results in activating the grab and move feature.

5.2.3. Zoom

Interviewees at large, seemed to think the gesture used for zooming was intuitive, but did not agree upon a straightforward execution of the feature. A possible justification for the difficulties, when scaling a 3D object in the program, might be the requirement of two hands. A few participants did enlarge the dice too much, because their hands were out of the Leap Motion devices frame.

5.2.4. Button

The main concern about the button for several interviewees was that they had issues with perceiving the location of the button in a virtual 3D space. As reported in the user survey, participants did not have a feeling for the deepness of the scenery. Others tried to press the button from the side, pushing it not on a linear angle. Consequently, the button got stuck several times. To resolve or minimize this issue, it is suggested to angle the button towards the middle of the scene, where the user is positioned.

5.3. Suggestions

In this paragraph, there will be various ideas and optimizations explained, that might improve this project, however they could not be implemented, due to a lack of time. It seems, that the zoom gesture usually performs accurately while zooming the object. However, the Leap Motion does rarely not differentiate between zooming and translation. Furthermore, the use of the palm to rotate an object is not the most intuitive method. It appeared that some users could not manipulate the object as fluently as the team hoped to. For this reason, the following improvements should be carried out with special attention to these features.

Translation: to grab the object by pinching was an acceptable idea. However, when users turned their hands face up, the virtual hand of the program simply could not understand that position, because the pinch will be obscured by the outside of the hand. Thus, it is recommended to implement a more intuitive gesture. One that mimics grabbing a real object with one hand, by using all five fingers for wrapping around the object and thus, grabbing the object.

Rotation: the use of the palm of the hand was less intuitive, few participants thought to put their palm inside the object and then start rotating the object. For this reason, it would seem logical to have the same hand gesture the translation possesses. That would reduce the learning curve (time you need to gain new skills).

Button: at the right part of the screen there is a button which allows users to reset the initial position of the object. While there are no significant complaints or issues when using this feature, it was seen that when left handers tried to press it they had more difficulties than those who are right handers. So, before starting the program there should be an option that asks you which your dominant hand is.

5.4. General analysis

5.4.1. Relevance

This program has been developed in order to facilitate the interaction of 3D objects. This project can bring lasting changes in the medical community. For instance, parts of the code could perfectly be used in other programs or applications.

5.4.2. Effectiveness

The objectives were changed as the semester progressed. Firstly, the objective was to add few additional features to the previous code, however the project group did not improve upon the prior project's code, due to compatibility issues on different operating systems. At that moment, objectives were drastically modified in order to reach the final goal, which allows surgeons to control three dimensional models while they are working. Another challenging goal was to develop a program that might be enhanced by future students. Furthermore, sometimes it was difficult to arrange meetings with the group members. At the end, the project could achieve almost all the main goals, such as develop a program, which users could manipulate 3D objects this involves translate them, rotate them and zoom in/out them and also, was able to run on Mac OS and Windows. The team required additional time, in order to complete the optimizations previously mentioned, resulting in a better interaction between the users and the program.

5.4.3. Efficiency

A Gantt diagram was used to coordinate tasks throughout the semester, so that one goal can be divided in various objectives. Subsequently, objectives were split into tasks for team members to finish in a certain time frame. To sum up, objectives were achieved on time.

5.4.4. Sustainability

Will there be an exit strategy for the project? There might be one, as the program is working well and most of the functionalities are easy to use even if one is not an advanced user in manipulating 3D models with Leap Motion. Exit strategies for the project:

- Firstly, the project might be enhanced by the next EPS students.
- Secondly, this project could contribute to improve open source world, being used in future applications, by letting people download it for free.
- Last one, the program could be sold to a private company as long as they were interested in it previously.

6. Conclusion

In conclusion, a prototype with basic features has been developed with the aid of a conducted user survey. Additionally, a documentation of the code has been written for future development.

After a careful inspection of the prior project's program, and its results, the project team agreed upon developing a new program for the sake of instant gesture recognition and the support of cross-platform compatibility.

The group implemented various features, such as rotating, scaling and translating a 3D object. Additionally, gestures for executing these features have been developed, providing the possibility to select a feature without physically pressing a button on a keyboard or computer mouse.

A quantitative method was used to get user data, and a survey was conducted among the users. The gathered data made it possible to set up statistics and formulate suggestions for evaluation and assessment of the program. Beside that, the project team discovered how one might utilize the Leap Motion device for their first time manipulating 3D objects.

In the end, the project team developed a prototype for surgeons to manipulate 3D objects directly in a more intuitive and comfortable manner. Instead of using a computer mouse indirectly, they now could utilize hand gestures to manipulate 3D objects. Due to the lack of time, further research and development could have been made. Hence, the project published the software on *GitHub* for future development. Leap Motion has the potential to enhance the human-computer interaction in a clinical environment. It is capable to revolutionize medical 3D and 2D imaging, due to its sterility, ease of use and low-cost barrier.

7. Personal Reflection (Belbin)

Leap Motion is a fascinating technology. As we were looking through all the projects the European Project Semester had to offer, we were all thrilled by the idea of this subject. Cooperating with a hospital to improve surgery using high technology was an exceptional opportunity for us. This project gave us the chance to work on a real product that might lead to a substantial impact for the future of surgery. Therefore, it granted us motivation to start the project.

Although, we tried to test the application of the former group and understood that it would not be possible to continue their work. A choice had to be made between two versions of the Leap Motion. We did not want to revert our work during the semester, thus it took us a long time to decide which solution will be the most stable.

When our choice of starting from scratch with the older version was made, we commenced programming. The coding levels of the team were very heterogeneous. Hence, the tasks were divided differently and time had to be given for the least experienced developers to help them. The good point behind this is that they have now a better understanding of the developer's way of working and have improved their skills with programming tools such as GitHub, Unity and StackOverflow.

As an alpha version was developed, we chose to divide the group in two subgroups. The two developers kept coding on the application for optimization while the two others were doing the user survey. This was an excellent idea because everyone worked more efficiently and the application was finished in no time. Besides, the user survey gave us a real understanding of the Leap Motion device and our software. We also learned a lot on the methods of surveying and it gave us a first experience on this matter for our upcoming projects.

At the end, the project achieved its goals. We are proud of what we have done and hope it will continue in the future with an EPS group or any team of developers.

This success is not only due to ourselves, but also to Louise Oram our supervisor. She helped us with various tasks and granted us constructive feedbacks during the entire project. Thus, her expertise guided us towards accomplishable goals. In addition, she was the contact with the hospital and consultant companies that could help us. She gave us a one-time opportunity to assists a real surgery and invited us to a meeting with Sopra Steria, a consultancy working on virtual technologies.

In a more personal way, our team had an outstanding time at HiOA; working on the Leap Motion project but mostly working with exceptional international students. Everyone in our group had a different way of working or even seeing the world. Communication was sometime difficult and lead to an argument. However, we always respected each other and the debate always finished with an agreement. Besides, we discussed a lot to understand each other, we accepted each other's differences and we took advantage of them. Different opinions give different approaches, it opened our field of vision. Moreover, an international group means a multitude of personalities. As you can see in the chart below, we were totally different characters. And we also had distinctive background, such as the field of study or even the education. We have benefited a lot from this diversity. The most experienced developers chose to lead the group as he was also a good coordinator and shaper. Hence, he could give the other clear tasks and goals that simplified the workflow dramatically. Nevertheless, the other members of the group had distinct qualities that improved the team work. Some used their technical skills to develop the application. Some used their communication skills to realize the user survey. Finally, some used their writing skills to have a clear academic report.

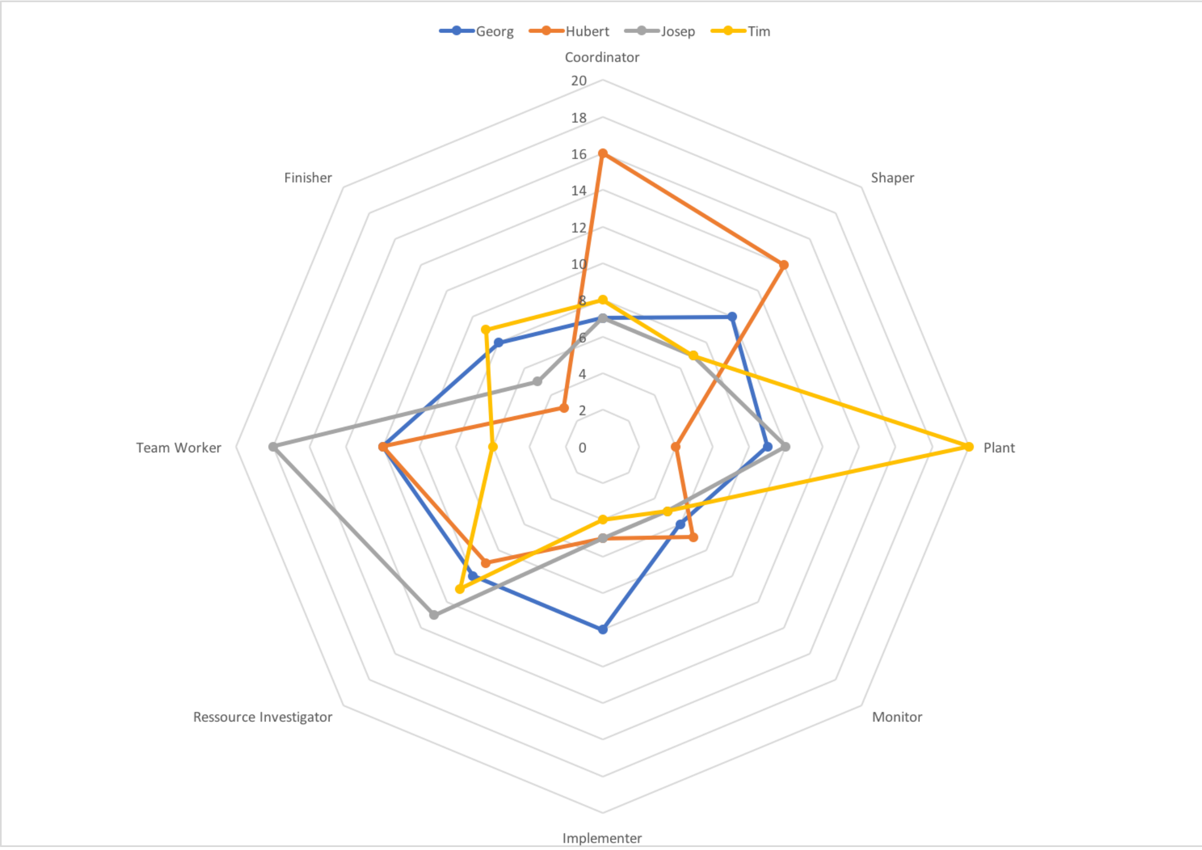


Figure 53: Belbin results of the four members of the group

To conclude with, this EPS project taught us several lessons. We learned what was Leap Motion and saw that it was not as advanced as it looks like. Some improved their programming skills and the others their teaching skills. Furthermore, we mainly learned how to work in an international team, listening to everyone's opinion, expressing ours and making compromises. Finally, we had to speaking English, when the moment was joyful or when it was stressful, when we felt excited or when we were exhausted. As no member of the team was from an English-speaking country, we all had to do this effort. It was sometimes challenging but we all faced it and overcame it. This project was unique and will lead us to many other international collaborations in the future.

8. References

Balakrishnan, R., Baudel, T., Kurtenbach, G., & Fitzmaurice, G. (1997). The Rockin'Mouse. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '97*. doi:10.1145/258549.258778

Noller, F. (2016, July 31). Getting started with simple 3D Buttons using Unity and Leap Motion. Retrieved from https://medium.com/@felixnoller/getting-started-with-simple-3d-buttons-using-unity-and-leap-motion-40d9efded317

9. Illustration directory

Appendix A: Source Code

Loader.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Loader : MonoBehaviour {

	void Awake () {
		Singleton.Instance.Init ();
		gameObject.AddComponent<UIManager> ();
		Singleton.Instance.UIMgr = gameObject.GetComponent<UIManager>();
	}
}
```

ButtonManager.cs

```
using System;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using Leap;

public class ButtonManager : MonoBehaviour {


	/**************
	 * Attributes *
	***************/

	public bool lockX;
	public bool lockY;
	public bool lockZ;

	public float returnSpeed;
	public float activationDistance;

	public Color inactiveColor;
	public Color activeColor;

	protected bool pressed = false;
	protected bool activated = false;
	public bool fading = false;

	protected Vector3 startPosition;

	/***********
	 * Methods *
	************/

	// Use this for initialization
	void Start () {

		// Remember start position of button
		startPosition = transform.localPosition;

		gameObject.SetActive (false);
	}

	// Update is called once per frame
	void Update () {
```

```
		float initPos = 0.0f;
		if (!lockX) initPos = startPosition.x;
		else if (!lockY) initPos = startPosition.y;
		else if (!lockZ) initPos = startPosition.z;
		float offset = (activationDistance - initPos) * 0.2f;

		if (transform.localPosition.z > offset)
			moveButton ();
		else
			transform.localPosition = startPosition;

		if (activated) {
			activated = false;
			Activation ();
		}
	}

	protected void moveButton()
	{
		// Use local position instead of global, so button can be rotated in any
direction
		// Lock disabled axis
		Vector3 localPos = transform.localPosition;
		if (lockX) localPos.x = startPosition.x;
		if (lockY) localPos.y = startPosition.y;
		if (lockZ) localPos.z = startPosition.z;
		transform.localPosition = localPos;

		//Get distance of button press. Make sure to only have one moving axis.
		float distance = GetDistance ();

		// Return button to startPosition
		transform.localPosition = Vector3.Lerp (transform.localPosition, startPosition,
Time.deltaTime * returnSpeed);

		float pressCompletion = 1.0f - ((activationDistance - distance) /
activationDistance);

		// button pressed
		if (pressCompletion >= 0.7f && !pressed)
		{
			pressed = true;
			activated = true;
			//Change color of object to activation color
			StartCoroutine(ChangeButtonColor(gameObject, inactiveColor,
activeColor, 0.2f));
		}
```

```
		// button unpressed
		else if (pressCompletion <= 0.30f && pressed)
		{
			pressed = false;
			//Change color of object back to normal
			StartCoroutine(ChangeButtonColor(gameObject, activeColor,
inactiveColor, 0.3f));
		}
	}

	protected IEnumerator ChangeButtonColor(GameObject obj, Color from, Color to,
float duration) {
		float timeElapsed = 0.0f;
		float t = 0.0f;

		while (t < 1.0f)
		{
			timeElapsed += Time.deltaTime;
			t = timeElapsed / duration;
			obj.GetComponent<Renderer>().material.color = Color.Lerp(from, to,
t);
			yield return null;
		}
	}

	// the button fades away and deactivates itself
	protected IEnumerator FadeAway(GameObject obj, float duration) {
		fading = true;

		float timeElapsed = 0.0f;
		float t = 0.0f;

		while (t < 1.0f)
		{
			timeElapsed += Time.deltaTime;
			t = timeElapsed / duration;

			Color colorAlpha = obj.GetComponent<Renderer> ().material.color;
			colorAlpha.a = Mathf.Lerp (1.0f, 0.0f, t);
			obj.GetComponent<Renderer>().material.color = colorAlpha;
			yield return null;
		}

		// For the fade away function, deactivates game object when transparent
		if (gameObject.GetComponent<Renderer> ().material.color.a < 0.05f) {
			fading = false;
```

```
				gameObject.SetActive (false);
			}
		}

		// to get the distance between the button and it's start position
		protected float GetDistance() {
			Vector3 allDistances = transform.localPosition - startPosition;
			float dist = 1.0f;
			if (!lockX) dist = Math.Abs(allDistances.x);
			else if (!lockY) dist = Math.Abs(allDistances.y);
			else if (!lockZ) dist = Math.Abs(allDistances.z);

			return dist;
		}

		// action of the button when pressed, for the ButtonManager it is change color
		public virtual void Activation() {
			float r, g, b;
			r = UnityEngine.Random.Range (0.0f, 1.0f);
			g = UnityEngine.Random.Range (0.0f, 1.0f);
			b = UnityEngine.Random.Range (0.0f, 1.0f);

			Singleton.Instance.Organ.GetComponent<Renderer> ().material.color = new
Color(r, g, b);
		}

		// the button disappears : fades away
		public void Deactivation() {
			if (fading == false) {
				StartCoroutine (FadeAway (gameObject, 0.5f));
			}
		}
}
```

ButtonVisibilityManager.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ButtonVisibilityManager : MonoBehaviour {

	protected GameObject movingButton;

	// Use this for initialization
	void Start () {
		movingButton = transform.Find ("MovingButton").gameObject;
	}

	// Update is called once per frame
	void Update () {

	}

	void OnTriggerEnter(Collider otherCollider) {
		if (otherCollider.transform.parent.name == "middle" &&
otherCollider.gameObject.name == "bone1") {
			movingButton.SetActive (true);
		}
	}

	void OnTriggerExit(Collider otherCollider) {
		if (otherCollider.transform.parent.name == "middle" &&
otherCollider.gameObject.name == "bone1" && movingButton.activeInHierarchy) {
			movingButton.GetComponent<ButtonManager> ().Deactivation ();
		}
	}
}
```

Rotation.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Leap;


public class Rotation : Gesture {

	Controller controller;
	public HandController handCtrl;

	private Quaternion oldHandRotation;

	// Use this for initialization
	void Start () {
		controller = new Controller ();
		oldHandRotation = Quaternion.identity;
	}

	private bool IsHand(Collider other) {
		if (other.transform.parent && other.transform.parent.parent &&
other.transform.parent.parent.GetComponent<HandModel> ())
			return true;
		else
			return false;
	}

	void OnTriggerEnter() {
		oldHandRotation = Quaternion.identity;
	}

	void OnTriggerStay(Collider other) {
		if (IsHand (other))
		{
			Frame frame = controller.Frame ();
			Hand hand = frame.Hands.Frontmost;

			Quaternion newHandRotation = handCtrl.transform.rotation *
hand.Basis.Rotation (false);

			if (oldHandRotation != Quaternion.identity) {
				Quaternion deltaRotation = newHandRotation *
Quaternion.Inverse (oldHandRotation);
				transform.rotation = deltaRotation * transform.rotation;

				//transform.rotation = handCtrl.transform.rotation *
```

```
hand.Basis.Rotation (false); //rotation
                                        Activated = true;
                              }

                              oldHandRotation = handCtrl.transform.rotation * hand.Basis.Rotation
(false);
                    }
          }

          void OnTriggerExit() {
                    Activated = false;
                    oldHandRotation = Quaternion.identity;
          }
}
```

Translation.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Leap;

public class Translation : Gesture {

	Controller controller;
	bool trigger_inside = false;
	public bool trigger_insideL = false;
	public bool trigger_insideR = false;
	public HandController handCtrl;
	public float oldZoomdistance;
	public bool isLeftFirst = false;
	public bool isLeftSecond = false;
	public bool zooming = false;
	public bool translating = false;
	public bool trigger_pinch1 = false;
	public bool trigger_pinch2 = false;
	public Vector3 thumb_tip1;
	public Vector3 thumb_tip2;


	void Start ()	{
		controller = new Controller ();
	}

	void Update () {
		Frame frame = controller.Frame ();
		HandList handsInFrame = frame.Hands;
		Hand hand = frame.Hands.Frontmost;
		trigger_pinch1 = false;
		trigger_pinch2 = false;
		Finger finger = new Finger (frame.Pointables.Frontmost);
		float THUMB_TRIGGER_DISTANCE = 0.025f;
		Hand firstHand = handsInFrame [0];
		Hand secondHand = handsInFrame [1];
		thumb_tip1 = firstHand.Fingers [0].TipPosition.ToUnityScaled ();
		thumb_tip2 = secondHand.Fingers [0].TipPosition.ToUnityScaled ();
		isLeftFirst = firstHand.IsLeft ? true : false;
		isLeftSecond = secondHand.IsLeft ? true : false;

		// checking if hands pinch

		for (int i = 1; i < firstHand.Fingers.Count && !trigger_pinch1; ++i) {
			Finger finger2 = firstHand.Fingers [i];
```

```
				for (int j = 0; j < 22 && !trigger_pinch1; ++j) {
					Vector3 joint_position = finger2.JointPosition
((Finger.FingerJoint)(j)).ToUnityScaled ();
					Vector3 distance = thumb_tip1 - joint_position;
					if (distance.magnitude < THUMB_TRIGGER_DISTANCE)
					trigger_pinch1 = true;
				}
			}

			for (int i = 1; i < secondHand.Fingers.Count && !trigger_pinch2; ++i) {
				Finger finger3 = secondHand.Fingers [i];

				for (int j = 0; j < 22 && !trigger_pinch2; ++j) {
					Vector3 joint_position2 = finger3.JointPosition
((Finger.FingerJoint)(j)).ToUnityScaled ();
					Vector3 distance2 = thumb_tip2 - joint_position2;
					if (distance2.magnitude < THUMB_TRIGGER_DISTANCE)
					trigger_pinch2 = true;
				}
			}

			// executing the movement

			if (handsInFrame.Count > 0) {
				if (finger != Finger.Invalid) {
					// translation function -  if hand is inside and pinched -> you
can move the object
					if ((trigger_pinch1 || trigger_pinch2) && trigger_inside &&
!zooming) {
						Activated = true;
						// use delta position
						transform.position =
handCtrl.transform.TransformPoint (hand.Fingers [0].TipPosition.ToUnityScaled ());
//translation
					} else {
						trigger_inside = false;
						trigger_insideL = false;
						trigger_insideR = false;
					}
				}
			}
		}

		// checking if hands are colliding with the object

		void OnTriggerStay (Collider other) {
```

```
		if(other.transform.parent.root.name == "RigidRoundHandLeft(Clone)"){
			trigger_insideL = true;
			} else if (other.transform.parent.root.name == 
"RigidRoundHandRight(Clone)"){
				trigger_insideR = true;
			}
			trigger_inside = true;
		}

		void OnTriggerExit (Collider other) {
			trigger_insideL = false;
			trigger_insideR = false;
			Activated = false;
			translating = false;
			zooming = false;
		}
	}
```

Zoom.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Leap;

public class Zoom : Gesture {
	Controller controller;
	private Translation T;

	void Start () {
		controller = new Controller ();
		T = gameObject.GetComponent<Translation>();
	}

	void Update () {
		Frame frame = controller.Frame ();
		HandList handsInFrame = frame.Hands;
		bool trigger_insideR = T.trigger_insideR;
		bool trigger_insideL = T.trigger_insideL;
		bool trigger_pinch1 = T.trigger_pinch1;
		bool trigger_pinch2 = T.trigger_pinch2;
		bool zooming = T.zooming;
		float oldZoomdistance = T.oldZoomdistance;
		Vector3 thumb_tip1 = T.thumb_tip1;
		Vector3 thumb_tip2 = T.thumb_tip2;

		if (handsInFrame.Count == 2 && trigger_insideR && trigger_insideL &&
trigger_pinch1 && trigger_pinch2) {
			float distance3 = Vector3.Distance(thumb_tip1,thumb_tip2)*50;
			if(oldZoomdistance == distance3) {
				zooming = false;
			} else {
				zooming = true;
				Activated = true;
				transform.localScale = Vector3.one * distance3;
			}
			oldZoomdistance = distance3;
		} else {
			Activated = false;
		}
	}
}
```

UIManager.cs

```
using System;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using Leap;


public class UIManager : MonoBehaviour {

	public UnityEngine.UI.Image gestureImage;

	// Use this for initialization
	void Start () {

		// Init for Gesture feedback icon
		gestureImage =
GameObject.Find("GestureIcon").GetComponent<UnityEngine.UI.Image>();
		gestureImage.enabled = false;
	}

	public void DetectGesture() {
		bool imageEnabled = false;
		foreach (Gesture gesture in Singleton.Instance.GetGestureList()) {
			if (gesture.Activated) {
				gestureImage.enabled = true;
				gestureImage.sprite = gesture.Icon;
				imageEnabled = true;

				// making sure translating icon gets selected if translating and
rotating at the same time.
				if(gesture.GetType().Equals(typeof(Rotation))){
					foreach (Gesture otherGesture in
Singleton.Instance.GetGestureList()) {

	if(otherGesture.GetType().Equals(typeof(Translation))&& otherGesture.Activated){
							gestureImage.sprite =
otherGesture.Icon;
							break;
						}
					}
				}

				break;
			}
```

```
		}
		if (imageEnabled == false) {
			gestureImage.enabled = false;
		}
	}

	void Update () {
		DetectGesture ();
	}
}
```

Gesture.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class Gesture : MonoBehaviour {

	public Sprite Icon;

	public bool Activated;

	// Use this for initialization
	void Start () {
		Activated = false;
	}

	// Update is called once per frame
	void Update () {

	}
}
```

ResetButton.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ResetButton : ButtonManager {

	// Virtualisation of the function Activation : Reset function is activated
	public override void Activation () {
		Singleton.Instance.ResetOrgan ();
	}
}
```

Singleton.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Singleton {

	/**************
	 * Attributes *
	***************/

	private static Singleton instance;

	public UIManager UIMgr;

	private List<Gesture> gestureList;

	public GameObject Organ;

	public Vector3 initialOrganPosition;
	public Quaternion initialOrganRotation;
	public Vector3 initialOrganLocalScale;

	/***********
	 * Methods *
	************/

	private Singleton() {}

	public static Singleton Instance
	{
		get
		{
			if (instance == null)
			{
				instance = new Singleton();
			}
			return instance;
		}
	}

	public void Init() {
		InitOrgan ();
		InitGestureList ();
	}
```

```
	public void InitOrgan() {
		Organ = GameObject.FindGameObjectWithTag ("Organ");
		initialOrganPosition = Organ.transform.position;
		initialOrganRotation = Organ.transform.rotation;
		initialOrganLocalScale = Organ.transform.localScale;
	}

	public void ResetOrgan (){
		Organ.transform.position = initialOrganPosition;
		Organ.transform.rotation = initialOrganRotation;
		Organ.transform.localScale = initialOrganLocalScale;
	}

	public void InitGestureList() {
		gestureList = new List<Gesture> ();

		Gesture zoom = Organ.GetComponent<Zoom> ();
		Gesture rotation = Organ.GetComponent<Rotation> ();
		Gesture translation = Organ.GetComponent<Translation> ();
		gestureList.Add (zoom);
		gestureList.Add (rotation);
		gestureList.Add (translation);
	}

	public List<Gesture> GetGestureList() {
		return gestureList;
	}
}
```

Appendix C: Installation Manual

1. Download and install the latest version of *Unity* (2017.1.1 or above).

2. Download the Leap Motion Core Assets v2.3.1 from GitHub and extract it.

3. Download the project from GitHub as a zip archive and extract the archive. (https://github.com/schurlbua/LeapMotion)

4. Open the folder of the project and open the file *DefaultScene.unity* with *Unity*, located in /source/Leap Unity SDK 2/Assets/DefaultScene.unity.

5. In *Unity* navigate to *Assets -> Import Package -> Custom Package…* and open the Leap Motion Core Assets v2.3.1.

6. Once a small window opens, click *Import* and wait till *Unity* has successfully installed the assets.

7. Due to the missing links of the object's scripts and materials, it is advised to follow further instructions on the project's GitHub. (https://github.com/schurlbua/LeapMotion)

Appendix C: Methods User Study

Script for presenting the Leap Motion features

“There are 4 features I want to show you before you have 3 minutes time to practice on your own and experience Leap Motion”

Translation:

“Now I will show you how you can translate the dice.”

Show the translation and emphasize on, that you have to pinch to grab the object. Just translate the dice a bit around.

Rotation:

“I will show you the rotation feature now.”

Show the rotation feature and mention, that the program differs between having only the hand in the cube and having the hand in the cube and pinching.

Zooming:

“I will show you the zooming function now.”

Show how you can zoom in and zoom out. Emphasize, that you have to be with both hands in the cube and pinch.

Button:

“I will show you the use of the button now.”

Move the dice away and press the button a few times. Later on, the button task always has to be after the translation task.

General Information:

Mention that the people testing the program can always ask us to reset the program. If they ask this, we will reset the program, but the time will keep on running.

Appendix D: Results User Study

Table 1: taken times of individual participants in seconds.

Tasks	Translation	Rotation	Zooming
#1	19,53	2,50	10,06
#2	19,88	18,80	15,14
#3	8,96	7,03	1,27
#4	12,72	12,49	70,62
#5	30,79	42,71	27,77
#6	22,62	5,73	11,20
#7	13,97	11,61	8,18
#8	55,36	17,14	8,31
#9	16,80	17,12	71,90
#10	45,30	17,58	8,40
#11	28,99	82,30	12,19
#12	13,76	14,25	11,06

#13	10,67	18,93	11,16
#14	36,84	19,05	34,53
#15	26,99	9,84	62,65
#16	14,00	7,82	10,42
#17	12,53	16,49	7,65
#18	14,43	17,58	20,71
#19	54,64	9,40	9,18
#20	39,48	5,21	12,05
#21	28,04	15,83	5,56

Table 2: Average times of different categories of participants

Task/Rubrik	Translation	Rotation	Zooming	Button
Average (21)	25,06	17,59	20,48	21,39
Median (21)	19,88	15,83	11,16	14,66
Boys (7)	19,12	29,14	30,99	19,34
Girls (13)	25,99	12	15,68	23,73

18-25 (17)	24,43	14,46	19,45	18,63
26-40 (4)	27,76	30,89	24,83	35,95
VG: 3-4 times a week (2)	42,72	26,06	18,48	14,05
VG: Once a week (3)	14,42	14,47	12,37	13,16
VG: A few times per year (4)	16,71	8,75	10,71	15,85
VG: not playing any (12)	27,57	19,91	26,09	27,46
Leap/VR no (19)	26,22	17,77	20,96	22,67
Leap/VR yes (2)	14,10	15,92	15,89	14,86
3D no (19)	25,89	18,10	20,75	22,63
3D yes (2)	20,08	14,55	18,84	17,72

Table 3: Standard deviations of different categories of participants

Task/Rubrik	Translation	Rotation	Zooming	Button
Average	13,81	16,56	20,88	16,35

Boys	7,35	23,76	26,11	20,04
Girls	13,84	5,55	15,65	14,38
18-25	12,81	8,88	19,18	11,21
26-40	17,17	29,76	26,49	25,04
3-4 times a week	11,93	16,66	9,30	2,55
Once a week	4,46	5,28	8,17	1,09
A few times per year	4,66	6,18	0,49	5,41
not playing any	13,71	19,18	25,52	19,61
Leap/VR no	14,03	17,39	21,84	17,02
Leap/VR yes	0,34	1,67	4,83	0,20
3D no	13,90	17,70	21,84	17,41
3D yes	12,06	5,35	13,64	5,77