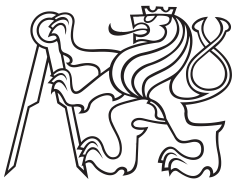
Master Thesis



Czech
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F3

Faculty of Electrical Engineering
Department of Computer Graphics and Interaction

User Interface Design for Augmented Reality 3D Modeler

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Supervisor: Ing. Martin Klíma, Ph.D.
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ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Ščupák** Jméno: **Michal** Osobní číslo: **460513**

Fakulta/ústav: **Fakulta elektrotechnická**

Zadávající katedra/ústav: **Katedra počítačové grafiky a interakce**

Studijní program: **Otevřená informatika**

Specializace: **Interakce člověka s počítačem**

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce:

Návrh uživatelského rozhraní pro 3D modelář rozšířené reality

Název diplomové práce anglicky:

User interface design for augmented reality 3D modeler

Pokyny pro vypracování:

Analyzujte existující produkt společnosti Misterine s.r.o. - Misterine Studio.
Na základě analýzy navrhněte nové uživatelské rozhraní produktu. Zaměřte se na část návrhu prezentace dat ve 3D prostoru.
Návrh nové podoby uživatelského rozhraní proveďte na úrovních low a high fidelity prototypu. Finální implementace bude provedena
programátorským týmem společnosti Misterine.
Prototypy popište tak, aby se daly finálně implementovat na cílové platformě.
Nad prototypy proveďte testy použitelnosti s Vámi vybranými uživateli podle profilu uživatelů odpovídajícího cílové skupině.
Akceptační kritéria:
1. Low-fidelity prototyp s popisem funkcionality jak grafickou, tak textovou formou
2. High-fidelity prototyp s podrobným popisem funkcionality, interakčního modelu (klávesnicí i myší), implementační okrajové podmínky
3. Provedené a analyzované testy použitelnosti low a high-fidelity prototypů.

Seznam doporučené literatury:

Alan Cooper: About Face - The Essentials of Interaction Design
Jakob Nielsen: Usability Inspection Methods

Jméno a pracoviště vedoucí(ho) diplomové práce:

Ing. Martin Klíma, Ph.D., Katedra počítačové grafiky a interakce

Jméno a pracoviště druhé(ho) vedoucí(ho) nebo konzultanta(ky) diplomové práce:

Datum zadání diplomové práce: **07.04.2021** Termín odevzdání diplomové práce: _____

Platnost zadání diplomové práce: **19.02.2023**

Ing. Martin Klíma, Ph.D. podpis vedoucí(ho) práce	podpis vedoucí(ho) ústavu/katedry	prof. Mgr. Petr Páta, Ph.D. podpis děkana(ky)

III. PŘEVZETÍ ZADÁNÍ

Diplomant bere na vědomí, že je povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací.
Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

. _____
Datum převzetí zadání

_____
Podpis studenta

Acknowledgements

First, I would like to thank my supervisor, Ing. Martin Klíma, Ph.D., for the opportunity to work on this thesis project as well as his guidance through my work. Next, I would like to thank to all of the study participants that spent their free time helping me to evaluate the design. Also, I want to thank my family and friends for their generous support through my studies.

Declaration

Prohlašuji, že jsem předloženou práci vypracoval samostatně a že jsem uvedl veškeré použité informační zdroje v souladu s Metodickým pokynem o dodržování etických principů při přípravě vysokoškolských závěrečných prací.

V Praze 10.8.2021

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Abstract

This diploma thesis addresses the user interface design for augmented reality 3D modeler. This work specifically targets the analysis of an existing Misterine s.r.o company's product - Misterine Studio, and a new user interface design. The primary focus is on manipulation with 3D models and their animation in particular. Similar state-of-the-art tools and the best usability practices were examined within the analysis part. Those findings were later used for the creation of a low-fidelity prototype of the so-called 3D scene workspace, that underwent user testing later on. Based on the initial test results, an improved user interface design was proposed in a form of high-fidelity prototype. Including precise specification as well as implementation details. Likewise, this design was evaluated by means of user testing. The test findings were then summarized and recommendations were made for further development of the Misterine Studio application.

Keywords: user interface, design, usability, 3D modeler, augmented reality

Supervisor: Ing. Martin Klíma, Ph.D.

Abstrakt

Diplomová práce se zabývá návrhem uživatelského rozhraní pro 3D modelář rozšířené reality. Konkrétně jde o práci zaměřenou na analýzu existujícího produktu společnosti Misterine s.r.o. - Misterine Studio, a návrh nového uživatelského rozhraní. Práce je zaměřena především na manipulaci s 3D modely a zvláště pak na animaci modelů. V rámci teoretické analýzy byla prozkoumána podobná řešení na trhu a prověřené principy použitelnosti. Následně byly tyto poznatky využity k vytvoření low-fidelity prototypu uživatelského rozhraní takzvaného 3D scene workspace, který byl následně uživatelsky testován. V návaznosti na výsledek testování low-fidelity prototypu byl vytvořen výsledný návrh uživatelského rozhraní v podobě high-fidelity prototypu spolu s přesnou specifikací a implementačními podmínkami. Na závěr je tento návrh a jeho použitelnost opět ověřena pomocí uživatelských testů, jejichž výsledky byly shrnuty pro následný budoucí vývoj aplikace Misterine Studio.

Klíčová slova: uživatelské rozhraní, design, použitelnost, 3D modelář, rozšířená realita

Překlad názvu: Návrh uživatelského rozhraní pro 3D modelář rozšířené reality

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Chapter 1

Introduction

Instruction manuals for a wide variety of products are all around us and everyone has used them from time to time during our life. With the development of modern technologies such as augmented reality (AR), we can provide much more precise user guides, technical documentation or maintenance instructions of everyday devices as well as sophisticated industrial machines. This is especially of importance in the ongoing phase of Industry 4.0 which is striving for interconnectivity, automation, machine learning, and manufacturing efficiency. By using AR technologies currently present on a modern smartphone, tablet, or AR glasses we can provide a realistic environment resembling very closely the physical device and its real-life use.

Misterine Studio is an application that is developed by a company called Misterine s.r.o.[1] The application enables its users to create such AR-supported technical documentation with the use of process workflow definition and assignment of 3D model animations to each task of the process. Therefore, this application is composed of two main parts. The first part focuses on the translation of the actual work steps into abstraction in a form of a detailed process scheme. The second part deals with the visualization of the process steps using 3D modeling and animation that is used for the AR purposes later on. Once the process workflow with its 3D scenes is set, Misterine provides the user with deployment of the data to their own cloud server where the data is stored and can be accessed for further use. Using Misterine App, free mobile application implemented for iOS and Android platforms, the user can login to the server and load a desired instruction manual. Moreover, by following the work instructions presented by the app on a mobile phone or tablet, the user is guided with the user of AR through the entire process.

The main application Misterine Studio is still in a development state and is lacking a usability analysis that would reveal its limitations and drawbacks. Furthermore, concepts and ideas regarding further development of nice-to-have features that improve the user experience (UX) with this application are missing. Hence, this diploma thesis aims to evaluate the application's user interface (UI) based on the comparison of the design principles used by the state-of-the-art (SOA) software solutions in the 3D modeling and animation field. Nevertheless, the comparison itself does not suffice to reveal

[1] https://misterine.com/

the application's shortcomings and therefore, good usability practices in this field are necessary to incorporate. In particular, the thesis mainly targets analysis and redesign of the second mentioned part which is used for the 3D model visualization, manipulation, and animation (3D scene workspace). The redesign consists of low and high-fidelity prototype phases. Subsequently, after each prototyping phase, usability tests evaluating the current design are performed by the end-users and the received feedback is considered in next development round.

First, typical users as personas and use case scenarios are presented to set up a foundation for upcoming analysis as well as the prototyping phase. Next, we analyze the existing UI design of the Misterine Studio and compare it with similar SOA tools available nowadays along with the good usability practices. The outcomes are then used to create the low-fidelity prototype which is evaluated by usability tests. Throughout the thesis, we also define precise requirements, implementation specifications for the UI, and also a new interaction model is proposed. Last, we create a high-fidelity prototype of the 3D scene workspace user interface taking the low-fidelity prototype's results into the account. This prototype is again evaluated by a usability study based on which the conclusion and further design changes are made. At the end, the findings of this thesis work are summarized in a conclusion chapter. Recommendations are made as to how to improve the usability of the application and the direction of further development are proposed.

Chapter 2

Augmented Reality for Technical Documentation

With the vast development of information and communication technologies in recent years, industrial manufacturing has become a lot more integrated with surrounding domains. The demand on time to market, delivery, process effectiveness, etc. is growing more than ever before. The use of state-of-the-art (SOA) technologies in the manufacturing industry is essential to success. A new trend is emerging, called Industry 4.0 [1]. German research supporting the implementation of Industry 4.0 into industrial companies introduces several design principles that form guidelines for this so-called industrial revolution [2].

Augmented reality (AR) is one of the modern tools that the industrial environment can benefit from. Especially one of the design principles which is the virtualization of technical documentation and use of modern human-computer interaction (HCI) techniques could be of interest in modern industry. Furthermore, there are many other aspects that could be implemented and improved such as overall integration of the systems together, internet of things (IoT) use and its utilization, and much more. Market research shows that, in general, companies are willing to invest in such innovations, however, several well-established practices, such as the use of printed documentation are hard to overcome since workers are used to their working style even if it is hard to update, renew, etc. [3]. Furthermore, higher error rates and higher attention demand are among the additional downsides of using traditional printed documentation. AR can significantly reduce these drawbacks. Moreover, AR has been proven as a valid solution able to present the essential information in the real workspace [4].

Figure 2.0.1: Augmented reality can increase effectiveness and bring real value to many industries [8].

As shown in [5], a user study confirmed that a well-developed AR documentation following the design principles as outlined in Industry 4.0 can make a significant improvement in terms of effectiveness and user experience (UX). The users confirm a higher understanding of the process. Some studies state that real-world graphical illustrations help users to reduce their cognitive load. The question regarding the cognitive load perceived by the participants is however not confirmed by other studies [6]. One important factor that influences user satisfaction and the perceived benefits of AR, is the type of AR realization. It has been shown that using Microsoft HoloLens[1] was much more efficient than using a smartphone to reproduce the AR. This conclusion was justified by faster reactions and orientation of the user in the space, which in the case of the Microsoft HoloLens took just moving a person's head.

In conclusion, modern well-designed AR is proven to improve the user's performance and relieve the cognitive load when in use for instruction manuals or technical documentation. Even though many companies are seeking to improve their manufacturing effectiveness with the use of AR, several legal limitations prevent a complete reform from the traditional printed documentation to the virtual one [5]. It is important to note that the quality of the design of the AR documentation, the calibration of the devices, etc. [7] are essential to the success of AR technology and its implementation in practice.

[1] https://www.microsoft.com/en-us/hololens

Part I

User Interface Analysis and Design

UI Analysis and Design Introduction

Since we have a good foundation of an already existing design of the Misterine studio, we already have a good sense of what the user's goals are and what we are trying to achieve. Even so, there is a need to set up clear scenarios of the software use and identify major problems in the current design which the newly introduced design should address [9].

As the literature suggests we will follow the process of first identifying the so-called typical users coupled with use case scenarios to observe and state requirements that our newly introduced design should fulfill. Based on these primary requirements we build up an analysis of the existing Misterine studios UI design and compare it closely with some of the SOA software tools available.

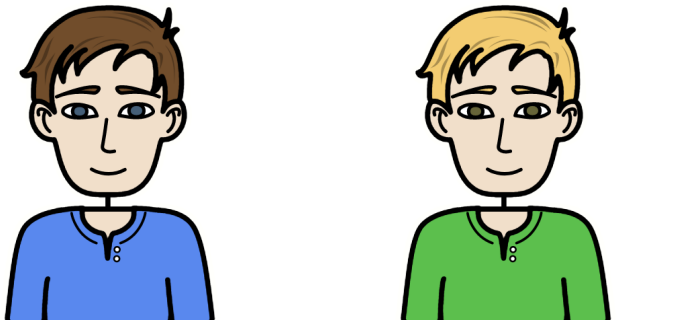
From here the common UI patterns will be identified as well as major usability principles researched to fit the use case.

Chapter 3

Users and Use-Case Scenarios

It is important to state at the beginning of the design who is going to use the 3D modeling tools. In our case of 3D modeling software used for AR model creation, we focus on two main groups of people using our system. The following illustrations were made with Storyboard That tool.[1]

3.1 Typical Users



(a) : Tomas - Graphic designer **(b) :** Adam - Design engineer

Figure 3.1.1: Typical user personas

3.1.1 Tomas - Graphic Designer

Tomas is a 31-year-old man living in Prague, a graphic designer, working for a company developing custom products. He is strictly oriented on the aesthetics of the products. He has wide experience with photo-video editing and several kinds of 3D modeling. His strong side is transforming real-life objects and processes into virtual 3D space based on customer needs. Tomas does not need to precisely know how the product works nor its precise specification for his work. The process scheme with basic information provided is enough for him to understand the concept. His goal is to visualize the product, create the animations, etc. for corresponding scenarios.

[1] https://www.storyboardthat.com/

- The 3D model is already created
- The process scheme is provided with a precise description of each task (by design engineers)
- The goal is to visualize the product using the 3D model and create animations of an object corresponding to each task in the process scheme

3.1.2 Adam - Design Engineer

Adam is a 43-year-old man living in Ostrava, a design engineer, working for an engineering company. He is experienced in engineering, understands how the products work and all the processes behind the scene. He has a good ability to translate physical steps during product, machine use, or maintenance into abstraction in a form of a process scheme. Adam likes the technical challenges and is confident in working with professional industrial design tools but does not have much experience with design aesthetics which is not his favorite part of product development. His task is to develop a working product from scratch and create process schemes for use or maintenance of the product.

- The 3D model is already created (or is created by the design engineer)
- The design engineer creates the process scheme and will not create the animations (respectively the design engineer just provides the process scheme to a graphic designer with a precise description of each task)

3.2 Use-Case Scenarios

3.2.1 Overall Walkthrough

This scenario represents a basic setup where we do not go into deep description and functionalities of the application. It should just form a bigger picture for a better understanding of the application design. The focus was on the 3D scene animation components of the application design at this point.

Process Scheme

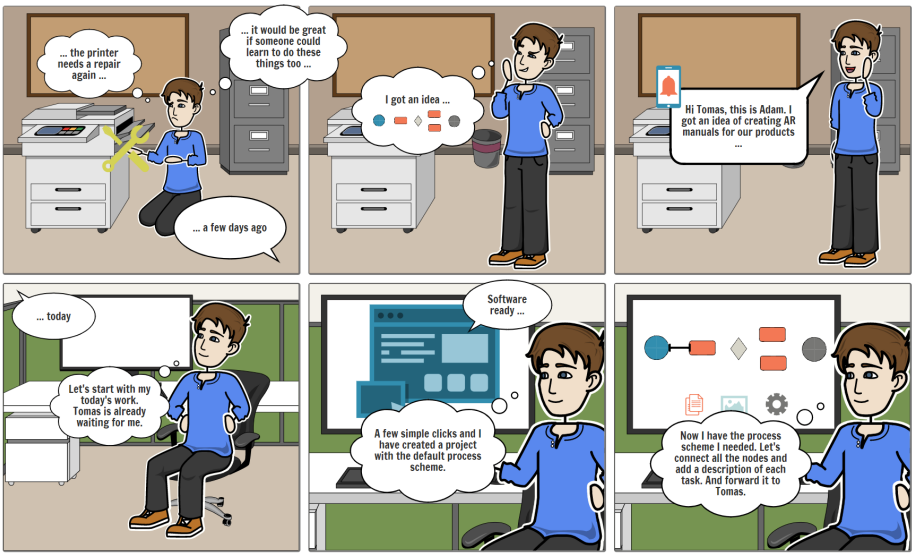


Figure 3.2.1: Adam - Design engineer, process scheme storyboard

Adam is a design engineer, he deeply understands the functionalities of the products he is working on. He was disappointed that many maintenance processes need to be done by himself only. So he got an idea to create intuitive user guides for the products, machines, so almost anybody can do the processes too. His today's work is to translate the manual process steps and create user guides, process schemes, for the products he is developing. The first thing he needs to do is to start up the software provided by the third-party company where he can create the process scheme, describe each several tasks, and provide it further. Adam creates a new project and adds a new process to it. This generates a simple template for him which he can use and analogously generate more tasks for his process. Using a toolbox menu with other scheme items provided he creates a complex process scheme. Adam names and describes each task and decision point to provide a clear explanation of the process for users and other developers. If he had any resources for the product, such as a 3D model or sheet with specifications, etc. he would have added these and link tasks with the corresponding resources, to provide the information along with the task description for later use. Finally, he connects all the nodes in the scheme and saves the project. Now he can forward it to his college Tomas who will add the visual part.

3D Scene Creation

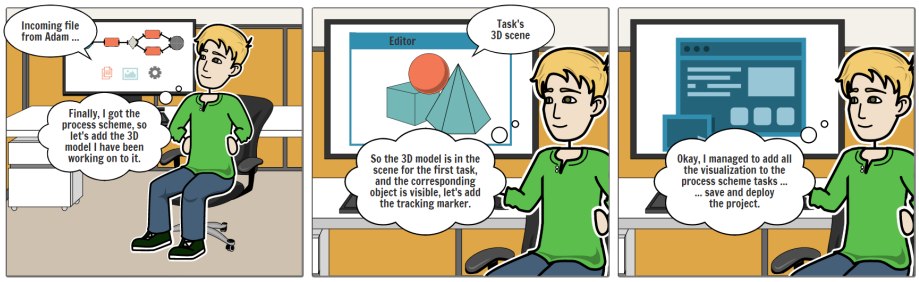


Figure 3.2.2: Tomas - Graphic designer, 3D scene creation storyboard

Tomas is a graphically oriented person, he was provided the process scheme and a very simple 3D model from Adam (from the previous scenario). His job is to visualize the whole 3D model at task one of the scheme. He opens the project in the provided application and sees the process scheme with a precise description of each task in the scheme. He adds a 3D scene to the first task and opens it. In a new window, Tomas imports the 3D model into the scene. When the model is loaded he selects the whole model, positions it into the origin, and makes it visible by moving it into the foreground. All steps he is making corresponds with the provided description from his college Adam who perfectly knows how the product works. He could do many more, such as animate a movement of the model, select just one part of the model to be visible, etc. but this was not his current goal. Last, Tomas adds the marker next to the object to make it trackable in space. In the end, he just closes the scene, makes sure that the process scheme did not change (except the first task), and saves or deploys the project.

3.2.2 Key 3D Scene Animation Tasks

This part consists of multiple task steps to represent many different combinations of all possible use-case scenarios for 3D scene animation. This simplification is used due to almost unlimited variations of possible operations and to create an easily understandable overview. Starting with simple animation track adding and ending with more advanced keyframe editing, etc. Later on before developing a high-fidelity prototype more precise list of requirements and features that could be implemented to our design will be introduced. These task steps will be further used as guidelines to investigate the SOA software to get ideas for our new design and mainly to research common practices and interaction principles. Followed by the same but more detailed analysis of the existing Misterine Studio's UI design which we will examine against the usability principles proposed by the literature.

Add Track with Animation

- Add track to an object
- Create animation, set keyframes
- Set animation parameters
- Edit the animation

Use Animation Preset

- Add animation preset to an object (e.g. screw in)
- Set animation parameters (duration, target axis, etc.)
- Edit the animation

Multiple Tracks and Track Editing

- An object already has one animation track
- Add another track
- Mute the track and un-mute the track
- Change its duration (with scale, or trim option)
- Reverse the track
- Duplicate the track
- Select multiple tracks
- Remove a track

Keyframe Editing

- An object already has one animation track with several keyframes
- Select one of the keyframes and move it in time
- Move to next or previous keyframe
- Duplicate a keyframe
- Select multiple keyframes
- Remove a keyframe

Animation Playback

- An object already has multiple animation tracks with several keyframes
- Playback whole animation
- Playback just one of the tracks

To illustrate the 3D scene animation process in better detail, the hierarchical task analysis (HTA) tree created with Draw.io[2] is provided below.

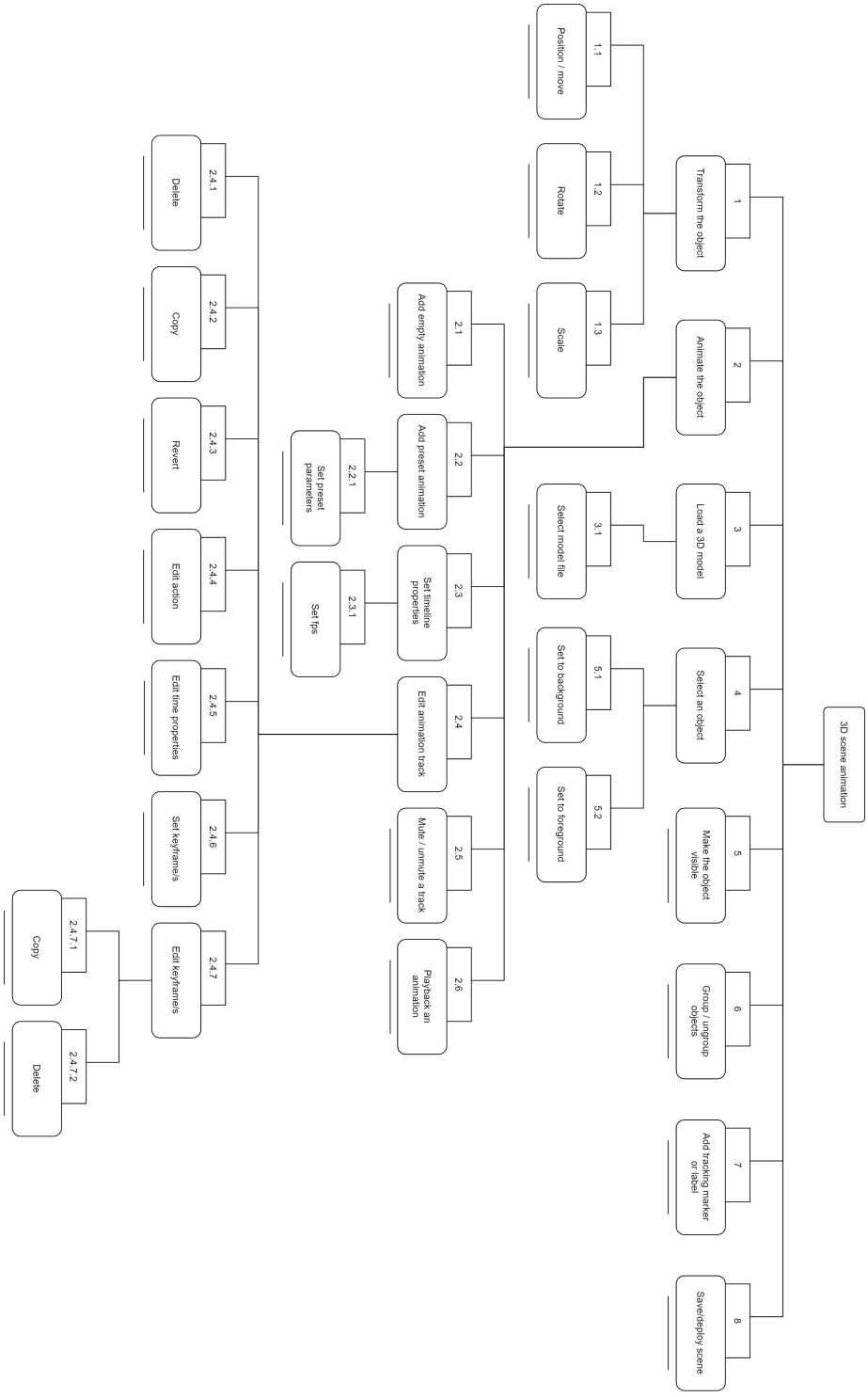


Figure 3.2.3: HTA - 3D scene animation

[2]https://app.diagrams.net/

Chapter 4

Usability Principles

There are many well-known general guidelines for successful UI design that our design should always follow. To depict each of them would be a long process nevertheless the main focus is the 3D modeling aspect of our application's UI. Therefore the goal of this section is to introduce some key issues and principles related to the design of the 3D modeler user interface.

The first rule essential for complex applications is the correct navigation between pages, workspaces, toolbars, etc. The design must reflect the use case scenarios. Moreover, unnecessary navigation can be the major reason for the unsuccessful design and is one of the most important aspects of the usability of our product.

The literature also states that the conducted research within this field clearly shows that the more separate windows or pages we use, the more we enforce the user's disengagement. Therefore, we strive to minimize window management and user excise by using compact and interactive design. For example, one can use split panes in one main window for more interactive impressions or divide the window using tab panes for less dependent content. The key is to visually inform the user where he is at. [9]

Nevertheless, it is convenient to use separation into workspaces for different tasks that provide distinct layouts and tools specifically needed for the desired task. Moreover, a user input such as transformation values to change an object's properties should be done using fixed form-based components, not pop-up dialogs that distort the user's attention and can overlay the object view. For numerical inputs, a good practice is to provide incremental controls to improve ease of use.

Components such as item explorers, are convenient to design with categorization and hierarchy in mind. This brings the user a quick and easy orientation as well as reduction of presented items at one time. [10]

Another important aspect is the availability and visibility of frequently used capabilities and tools. These should be always visible and logically grouped together facilitating quick orientation and user-friendliness of the design. Contrary to that, separating and/or hiding tools into tab panes should be avoided as it creates confusion, which can lead to desperation and ultimate user dissatisfaction and excise. At the same time, these tabs are impossible to design so the label is well understood by the user, and the tab

contains the tools the user intended to use. [9] However, reasonable user customization of the tool or component layout can be beneficial [10].

As our minimum requirements for the Misterine Studio use in further chapters state, the mouse and keyboard are fundamental for good UX of our application, despite this fact we should fully or at least maximize the support for both of the controllers for all the navigation and manipulation tasks since there are users with different habits and approaches.

Moving on to 3D object manipulation or generally object manipulation we need to bear in mind that working with such a complex application takes time to learn and needs continuous practice. Even familiar user has to preserve attention for many sequential actions that are required to fulfill each task and therefore, we strive to minimize additional cognitive load. Using direct manipulation (manipulation by clicking and dragging things) is the key. Essential to successful direct manipulation is that the user can manipulate only visible objects displayed in the current context and the user must be provided with rich visual feedback.

To extend the functionality of the mouse it is well-established to use so-called meta-keys (ctrl, alt, shift keys). A technique called cursor hinting can show the meanings of the meta-keys pressed which directly lets the user know what action the mouse is ready to execute. Crucial when implementing a mouse click or selection of an object is to follow two principles. On mouse-down, over an object, the object should get selected. Contrary to that on mouse-down over controls, the UI should propose an action, while on mouse-up the action is committed. A nice illustration of this is the check box in Windows XP on the picture below.

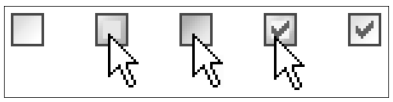


Figure 4.0.1: Stages of a check box in Windows XP - a) unselected, b) mouseover (hover), c) feedback to click (mouse-down), d) click released (mouse-up) with a hover, g) check box checked without a hover. [9]

This concept of visual indication is best for controls, toolboxes, menus, etc. The manipulable objects should rather prefer cursor hinting when the cursor immediately indicates the possible action.

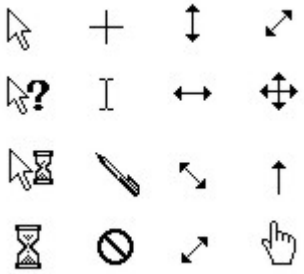


Figure 4.0.2: Example cursor types [11]

Apart from the visual aspects while selecting an object the guidelines state that an object-verb command order, when we first select the object to be operated and then choose the action (verb) to be executed, is more user-friendly. The user can do group selection using the click-and-drag principle to select multiple items (visually creating a rectangle around them) or additive selection using for example a meta-key while clicking the next items. Afterward, the tool, action, can be selected and executed. While the rule of mutual exclusion should be followed, this means that when a user selects an object or objects the selection remains until a new selection is made. In all of the cases, the selection should be always visually highlighted and clear to the user.

When moving an item on a pane the auto-scroll should be applied to the direction of the object going beyond the pane. The object we manipulate should be always visible. Furthermore, to prevent undesirable repositioning, the design should implement a threshold when the mouse movement is ignored. The proposed value of this threshold is 3 pixels in each direction. Another similar feature to this is the fine-tuning of the mouse movement when precise manipulation is desired. Any application that requires a precise positioning or generally precise manipulation should provide a variant of such control. This is commonly done using a meta-key while dragging when the mouse movement to cursor movement ratio is adjusted. The proposed ratio is that one pixel of the object movement translates to 10 pixels of mouse movement when in the precision mode. The next and very helpful feature is a constrained drag that using a meta-key while dragging restricts the manipulation to a single dimension. This helps the user and relieves some of the necessary attention and motor skills. Last but not least property is to provide a user with so-called snapping to the guidelines, or grid while dragging, again using a meta-key to enable it.

When focusing strictly on the 3D aspects the trend of multiple viewpoints implemented as a multipane window when a user can maximize one of the views has proven to be more effective than several disconnected windows due to a user's disengagement. A good practice is to use baseline grids in the 3D object view to show the virtual floor and walls inside the scene for each axis. This feature improves the user's orientation in the 3D space as well as helps when manipulating the object. The next important aspect is the

perception of depth. This is usually done by dimming the objects further in the scene, this applies also to a single object's surface. This technique is sometimes computationally demanding so another possibility to achieve a similar result is to use just a horizontal floor grid and vertical pole in the center of the object. As a user moves or rotates the object the pole is moving to but staying vertical, and therefore showing its position on the floor grid. [9]

As mentioned several times before the key is to visually highlight and support the cognition of what is happening, which object is selected, etc. Since there are usually many controls and options in the applications using 3D space, the crucial is to implement meaningful meta-keys and keyboard shortcuts for efficient workflow. Coupled with well-implemented tooltips or hints these practices create basic guidelines for a successful and efficient user interface.

Chapter 5

UI Analysis

5.1 State-of-the-Art Tools Analysis

State-of-the-art (SOA) analysis of tools that are nowadays available. We will essentially focus on 3D object animation tools, their capabilities as well as ease of use. Our main animation domains are the rotation, position, and opacity of a 3D object. The goal is to analyze existing tools and create a summary of the best approaches from the UX view. In each sub-analysis, the same tasks were performed based on the use-case scenarios from the second chapter to enable the software comparison.

Name	Support, source	Used license	Commercial license prizing
Inventor Profesional	https://www.autodesk.com/education/home	1-year educational access	1-year $2,085
3ds Max	https://www.autodesk.com/education/home	1-year educational access	1-year $1,620
Fusion 360	https://www.autodesk.com/education/home	1-year educational access	1-year $495
Cinema 4D	https://www.maxon.net/en/educational-licenses	6-month educational licensing	1-year $719
Blender	https://www.blender.org/download/	Open-source	Free
Houdini 18.5	https://www.sidefx.com/	Learning edition	1-year $1,995
Clara.io	https://clara.io/pricing	Basic	Custom plans

Table 5.1: State-of-the-art tools used in the analysis

5.1.1 Inventor Profesional

The first analyzed tool is the Invertor Profesional[1] by Autodesk Inc. This product mainly aims at 3D mechanical design, documentation, and product simulation. The animation of the 3D model takes place in a separate component called Invertor Studio. Here you can see the toolbar with all the tools needed for basic animations.

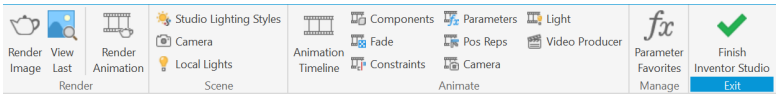


Figure 5.1.1: Inventor Profesional - Inventor Studio toolbar

[1] https://www.autodesk.com/products/inventor/

Animation Creation

- By clicking on the Animation Timeline button we start to create our first animation. The timeline opens in a separate window (visible on the following screenshot).

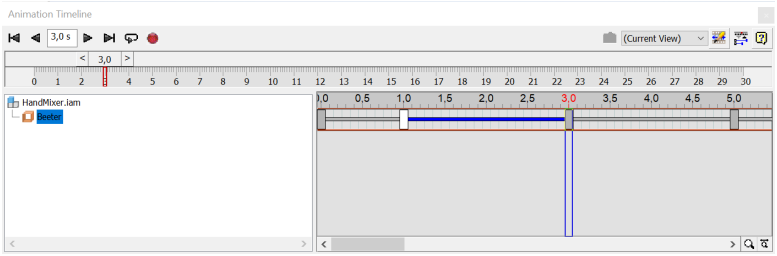
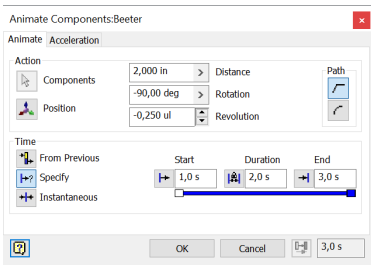


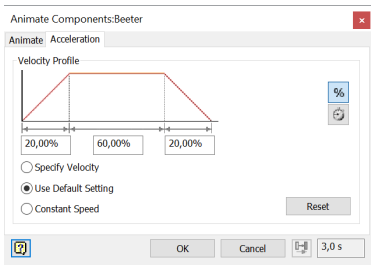
Figure 5.1.2: Inventor Profesional - a timeline with an animation

- If we are about to add an animation to an object/component the easiest way is to simply click on the component and then click on the Components button on the top bar which brings up the Animate Components window. The alternative way to add an animation to a component is to directly click on the Components button on the top bar with no object selected. This brings up the Animate Components window where on the tab Animate we can select components to animate by clicking on the cursor pictogram button and then the components.

- In the Animate Components window, we have two main tabs. In the Animate tab, here we do all the movement setup and select the start, duration, or end time of the animation. The second tab is called Acceleration, here you can modify the behavior of the movement/animation speed throughout the time range (ease in/out).



(a) : Animation propetries



(b) : Transition setup (ease in/out)

Figure 5.1.3: Inventor Profesional - animation properties (Animate Components)

- The position and rotation of a component can be achieved by clicking on the x-, y-, and z-axis arrows pictogram button. It will enable the axis arrows to be visible in the view window for the component selected previously. By right-clicking and dragging the arrows we can move (click on the end of the arrow) or rotate (click in the middle of the arrow) the

component with respect to the axis. Or we can do the movement on the selected plane.

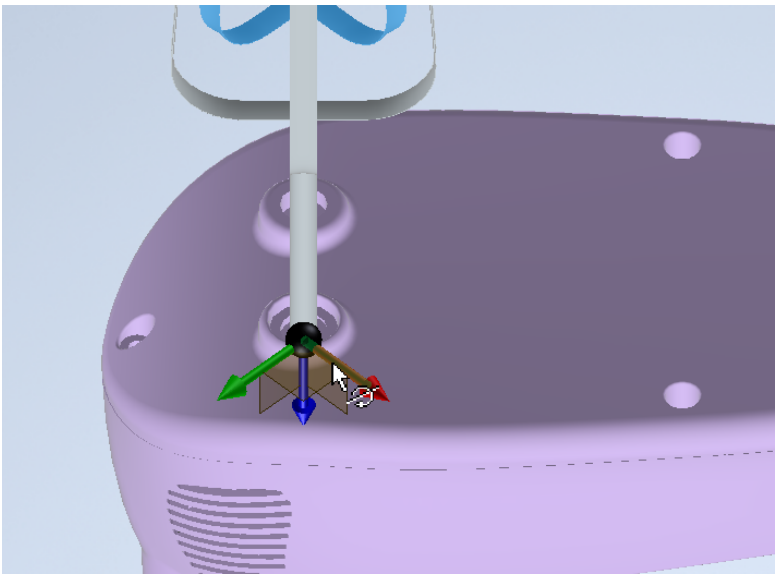


Figure 5.1.4: Inventor Profesional - object transformation controls

The movement can be also specified by inserting specific numbers (x-, y-, and z-axis movement in inches, or rotation in degrees) in corresponding fields.

- When we are finished with the animation we simply press OK in the Animate Components window. We can see the animation timeline in the Animation timeline window with our newly added animation highlighted.

- At the timeline, animations can be edited by double-clicking, or by right-clicking the animation we bring up the context menu where the animation can be copied, edited, deleted, or mirrored (copies and pastes reversed animation), furthermore, the animations can be moved, shortened, extended.

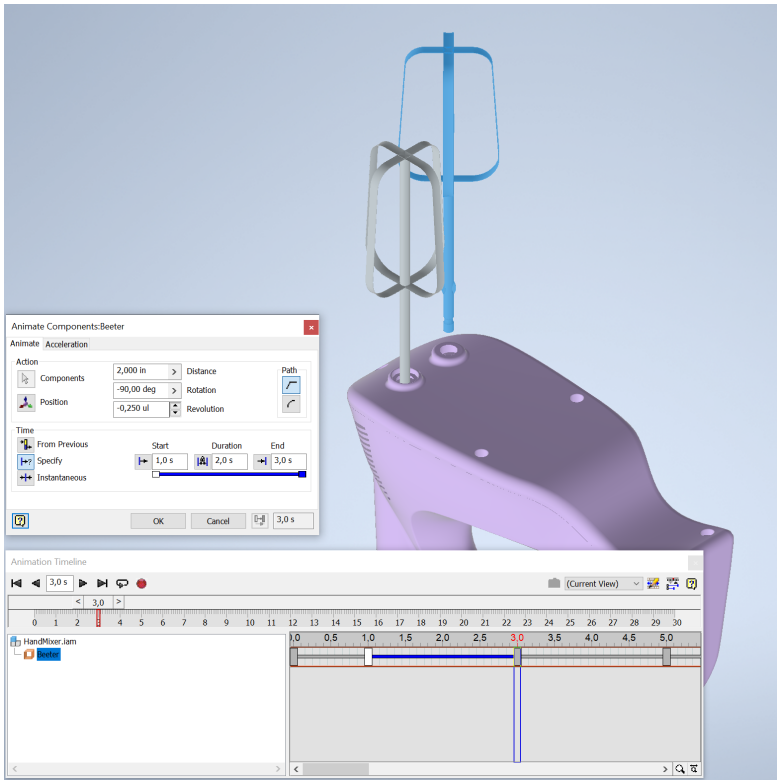


Figure 5.1.5: Inventor Profesional - editing animation (Animate Components)

- The final Animation timeline can be found in Model directories - Animations. We can name each animation to keep everything clear. This is useful for later editing.

Figure 5.1.6: Inventor Profesional - model explorer (animations)

5.1.2 3ds Max

3ds Max[2] as Autodesk Inc. states is a 3D modeling and rendering software for design visualization, games, and animation. The tool is more artistic oriented offering a very rich palette of powerful tools. In our case, this software and its capabilities are a bit overwhelming for our needs, but also the simple stuff can still be quite easily done in this software. We will skip the more advanced animation tools, camera view settings, etc. But all the controls can be easily found behind the control tab called Animation.

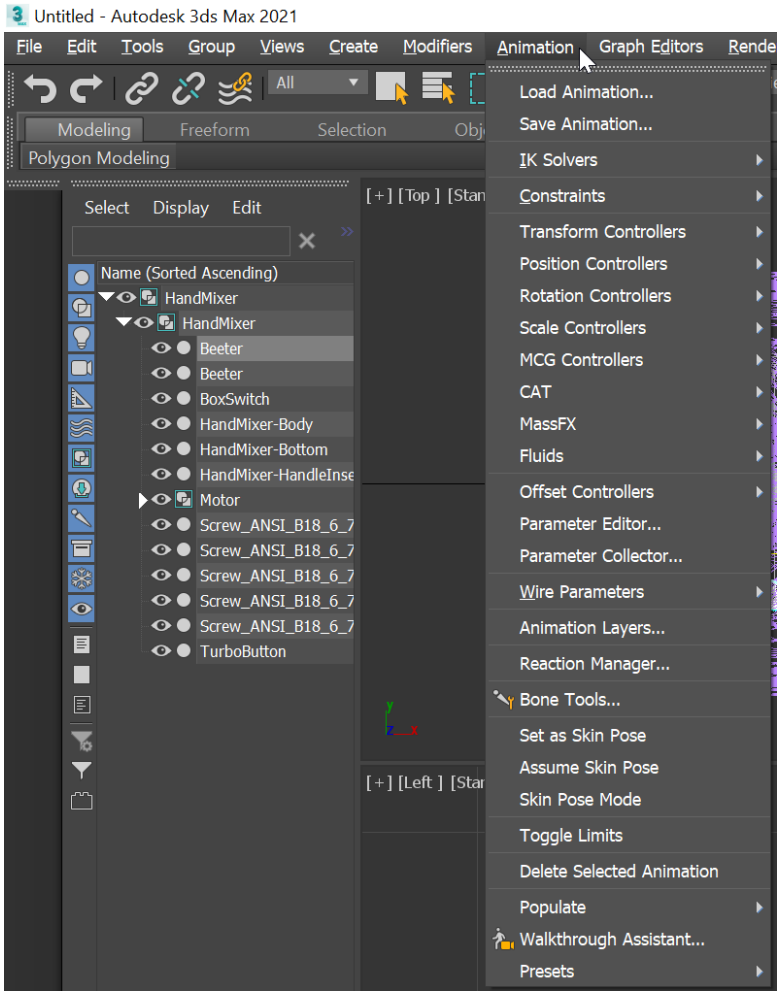


Figure 5.1.7: 3ds Max - animation context menu

Animation Creation

For our purposes, we will use the timeline toolbar at the bottom of the editor by default. Here we can find all the tools needed for time management of the animation, keyframes settings, and other control features.

[2]https://www.autodesk.com/products/3ds-max/

- The animation creation process starts with the selection of objects which we want to animate. Simply by clicking on the object we select it and the animation timeline at the bottom enables.

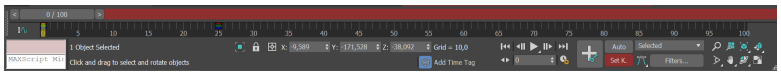


Figure 5.1.8: 3ds Max - timeline

- With the timeline, we are able to select a time point (frame) while using the main toolbar to move, rotate, resize, etc. to a position or state, we want it to be at a certain time.

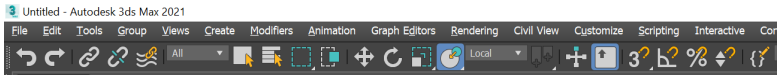
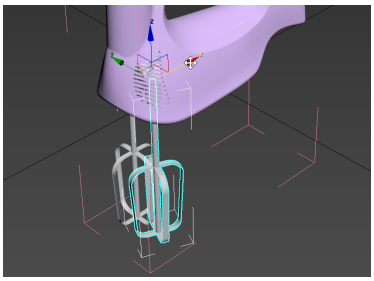
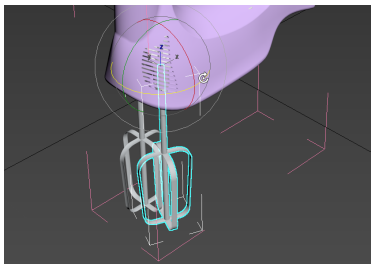


Figure 5.1.9: 3ds Max - main toolbar

- The position is set similarly as in the Inventor. By clicking on the Select and Move button we bring up highlighted x-, y- and z-axis for a selected object. Clicking and dragging on one of the axes performs the movement. The rotation is analogous (Select and Rotate button) except here we have three circles for better visibility of the movement around each axis.



(a) : Position controls



(b) : Rotation controls

Figure 5.1.10: 3ds Max - object transformation

For more precise movements there are available input fields below the timeline where we can state the amount of the movement in each direction. When we select the rotation, these coordinates change into degrees of rotation around a particular axis.

- The whole animation begins when creating a keyframe. This can be done automatically (pressing the Auto button at the bottom timeline toolbar), in the sense that a keyframe is created right away at a time point we are currently at and it records the position of the selected object at that point. This is useful for some simple animations. To have better control of the keyframes we need to press the Set Keys button. In this case, we have to always click the Set Keys button (shortcut-key K) to record a specific position of the object at a certain time point.

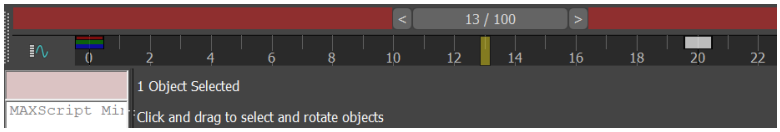


Figure 5.1.11: 3ds Max - partial timeline with keyframe

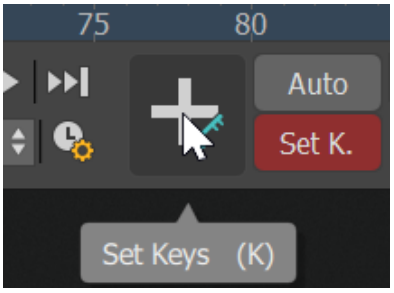


Figure 5.1.12: 3ds Max - keying setup (setting key)

- Keyframes are later visible at the timeline where they can be furthermore edited, deleted, moved in time, etc. The key role here plays the context menu which we bring up by right-clicking a keyframe.

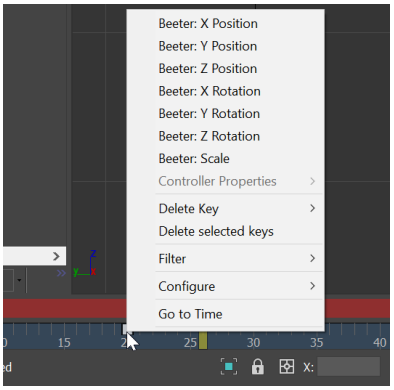


Figure 5.1.13: 3ds Max - keyframe context menu

- Similarly, as in the Inventor software, there are more options for the behavior of the speed of the movement/animation throughout the time (ease in/out). Here we have even more options using the Curve Editor (Open Mini Curve Editor button next to timeline) where all the parameters mentioned before can be also edited and the whole animation can be created here as well.

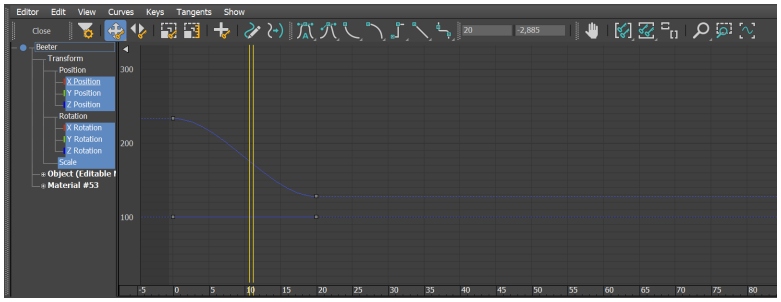


Figure 5.1.14: 3ds Max - advanced timeline F-Curve view

5.1.3 Fusion 360

Fusion 360[3] is a more lightweight but still capable 3D modeling software again from Autodesk Inc. The software provides us everything we need for our simple animation in an easy and understandable way.

Fusion 360 user interface is divided into several workspaces. The one we are interested in is the Animation workspace.

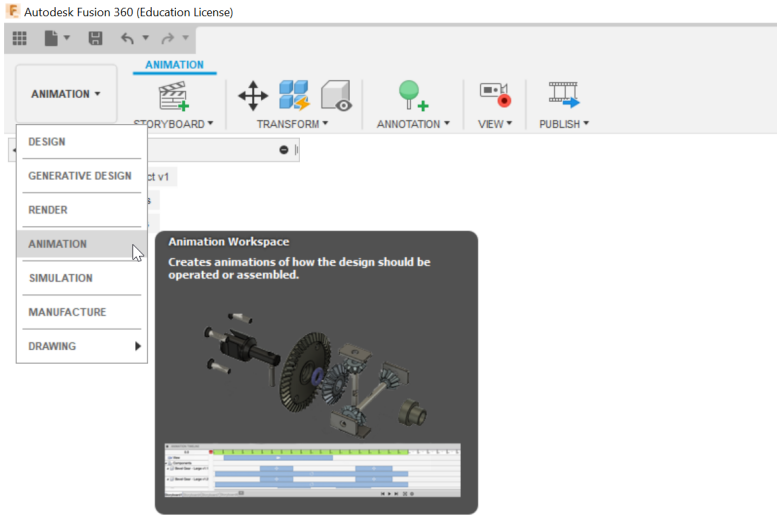


Figure 5.1.15: Fusion 360 - workspace options (Animation)

Animation Creation

By simply clicking on its button on the main toolbar on the top of the window we enter the required workspace to do our animation job.

- By clicking on the New Storyboard button on the top toolbar the animation process begins. This brings up the animation timeline at the bottom of the screen.

[3] https://www.autodesk.com/products/fusion-360/

Figure 5.1.16: Fusion 360 - Animation workspace toolbar

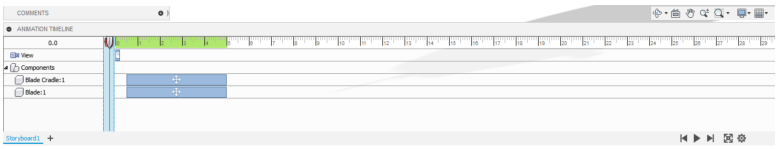


Figure 5.1.17: Fusion 360 - a timeline with movement animation

- Now we need to select an object or component that should be animated. This is possible in the project list (explorer) on the left of the window or just simply by clicking on the item. When an object is selected the object is nicely highlighted also in the explorer.

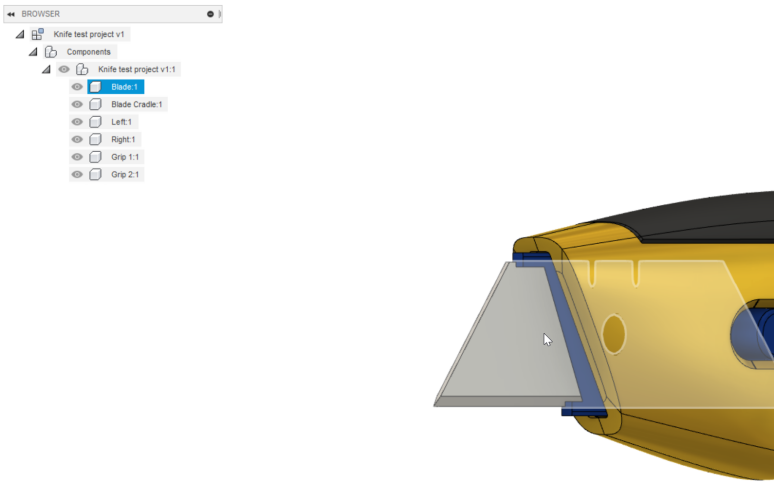
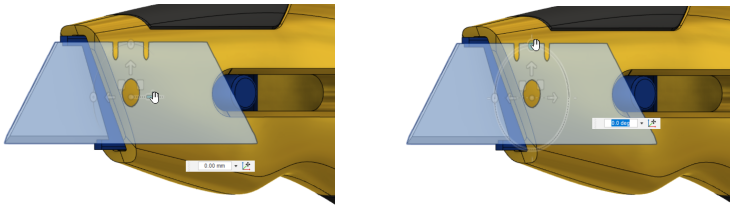


Figure 5.1.18: Fusion 360 - object selection and explorer highlighting

- At this point, we need to tell the software how to move the selected object and create the animation. This is made pretty easy in Fusion 360, without the need of setting any keyframes to the timeline. When the object is selected there are immediately visible options on how we can move the object. One straightforward option is to use these arrows in each axis direction and move the object or rotate it with a corresponding circular slider around an axis. When doing so there are available input fields for the insertion of a precise amount of the movement needed.



(a) : Position controls **(b) :** Rotation controls

Figure 5.1.19: Fusion 360 - object transformation

The other more advanced method is to use the toolbar at the top of the window that offers other interesting features such as for example explode transformation preset which makes the well-known explode animation creation very easy with this tool. The screenshot below focuses on the Transform Components function which provides a more precise setup of simple object movement.

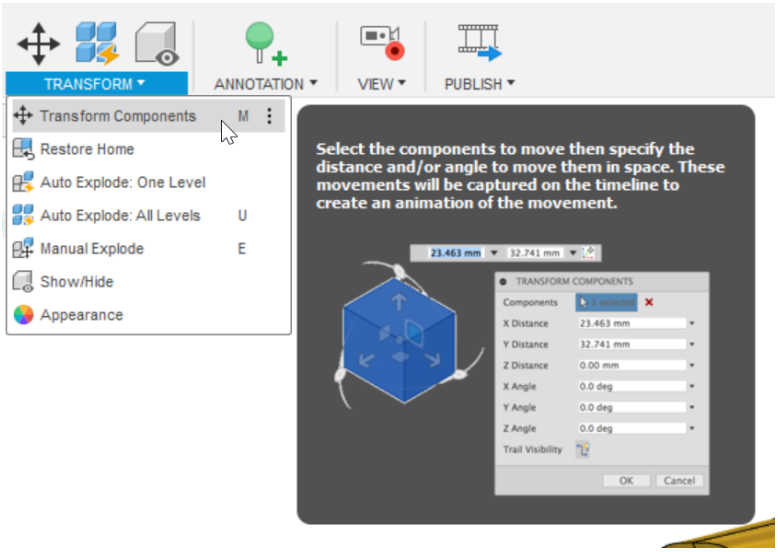


Figure 5.1.20: Fusion 360 - transform tools

- The animation and its "keyframes" are captured as we move with the object. So if we select a time point at the timeline and move the object from its previous state the software records its final position and creates an animation. Each animation is then visible at the timeline with a small pictogram showing if its view/camera movement, object translation, or its rotation, etc. The explorer on the left next to the timeline shows us what object is animated and which animation belongs to the object.
- The animation duration, start time, etc. can be edited by right-clicking on the animation bar/box (visible on screenshot below). The duration can be also easily changed by dragging one of the ends of the bar/box.

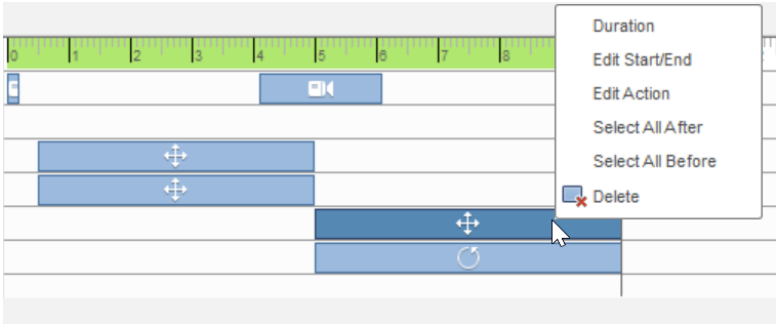


Figure 5.1.21: Fusion 360 - animation context menu

5.1.4 Cinema 4D

Cinema 4D[4] is one of the most popular and very capable 3D modeling, visualization, and animation software. The capabilities that this software has to offer are far beyond our use case, we will focus mainly on the simple animation creation as it was with the previous software we analyzed so far.

Animation Creation

The first thing to start animate an object is to switch into the Animation layout which adds the animation timeline and all its features. This is done by clicking and changing the layout in the top-right corner of the window.

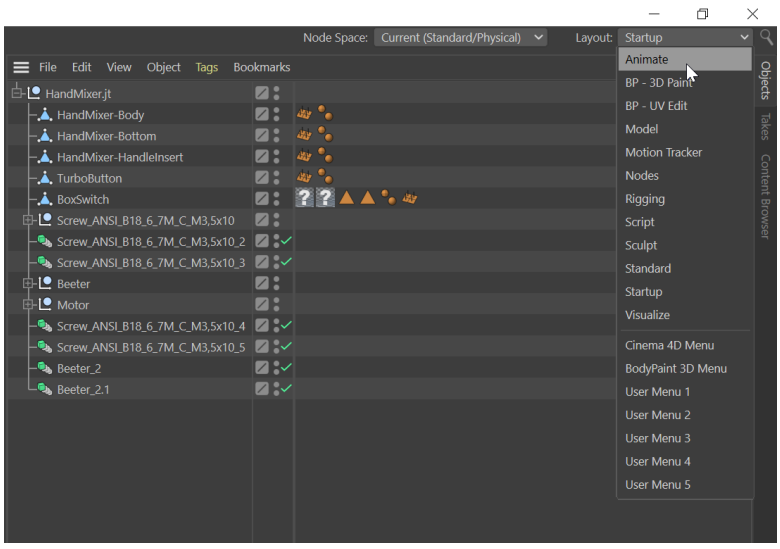


Figure 5.1.22: Cinema 4D - workspace layout options

- With the animation layout set, we can see the animation timeline at the bottom with all its controls. The animated objects are nicely visible on the left with its keyframes on the timeline. All the controls for translating, rotating, etc. an object are on the top of the window.

[4] https://www.maxon.net/en/cinema-4d/

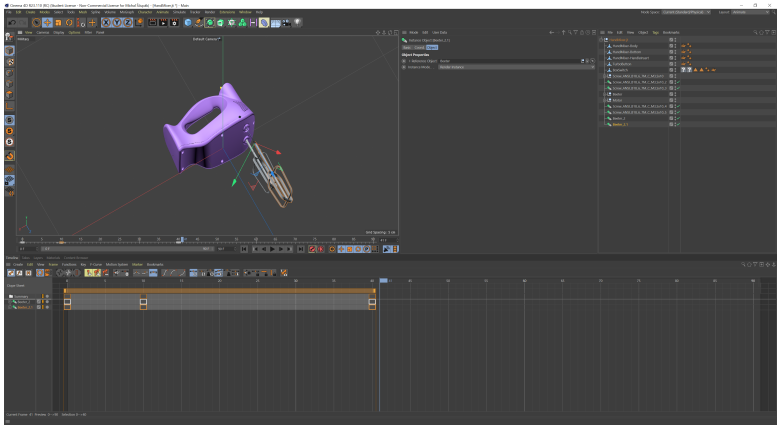


Figure 5.1.23: Cinema 4D - Animate layout view

- The animation of a translation is done similarly as in previous software. To change position or rotate an object we use the tools provided on the top toolbar. The nice feature here is the possibility to select/mute each axis to make it simple to move the object in the desired direction and therefore prevent any mistakes. To record the movement, we need to move in the time on the timeline at the bottom.

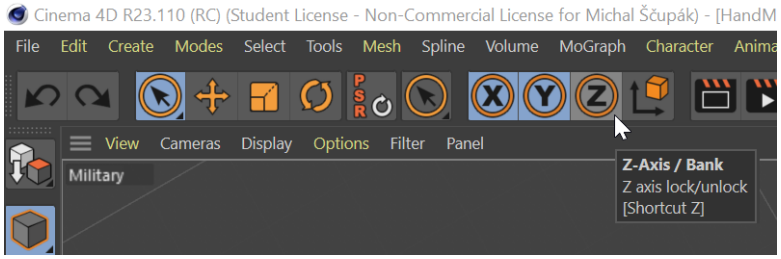
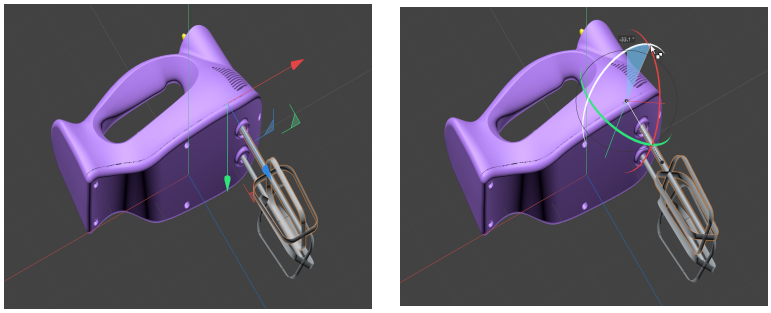


Figure 5.1.24: Cinema 4D - toolbar with axis lock/unlock

- The movement can be again created by dragging an axis arrow or a rotation slider. While moving the object the software is showing the amount of movement which for better precision can be set separately in corresponding input fields.



(a) : Position controls **(b) :** Rotation controls

Figure 5.1.25: Cinema 4D - object transformation

- The keyframes can be set manually or they are recorded with each movement of an object and the time point on the timeline. To be more precise we can set what type of movement should be recorded and which not. In our case, we will focus on setting the keyframes manually. This is done by moving to a specific time point on the timeline, moving the object to a state we want it in, and pressing the key button (Record Active Objects).

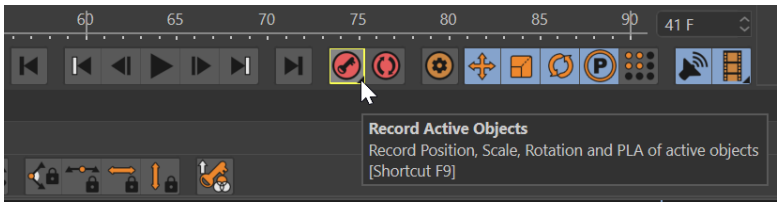


Figure 5.1.26: Cinema 4D - auto-keying setup

- The standard view of the timeline offers a view of each object animation with its keyframes. These can be further edited at this point, each keyframe can be moved, the transition can be changed (ease in/out), or the whole timeline can be adjusted, etc.

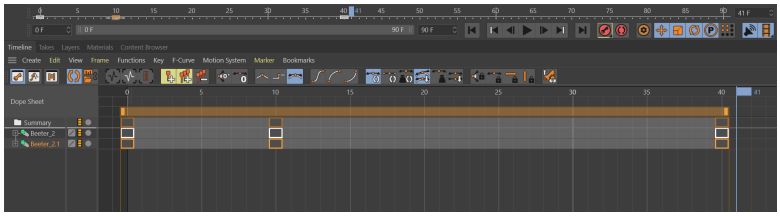


Figure 5.1.27: Cinema 4D - a timeline with keyframes

- There are many advanced features in this software which we are not able to cover. For example, the F-Curve view of the timeline offers a nice adjustment of each animation, where we can, even more, control the movement in time.

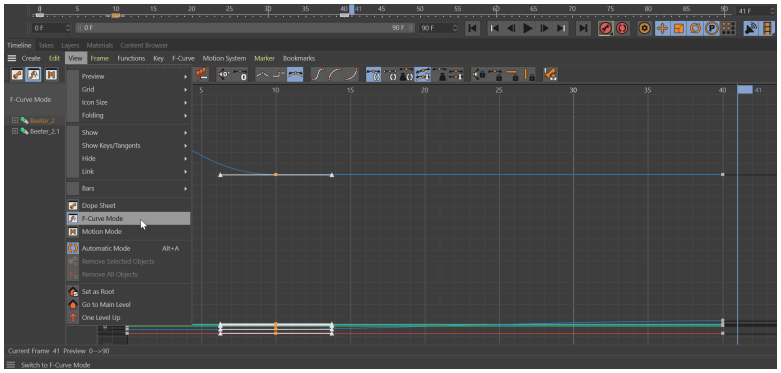


Figure 5.1.28: Cinema 4D - advanced view options (F-Curve view)

5.1.5 Blender

Blender[5] is the only free and open-source 3D modeling and animation software in our set. Due to its nature, it has a huge community with many contributors. Blender has very advanced features for example used by game developers which we will not be able to cover but it is good to know they are available.

Animation Creation

The first thing to do when starting with animation in Blender is to change the workspace to the Animation workspace which provides a much better layout and tools for the purpose. The change of the workspace is done by clicking on the plus icon add workspace next to the workspace tabs on the top of the window.

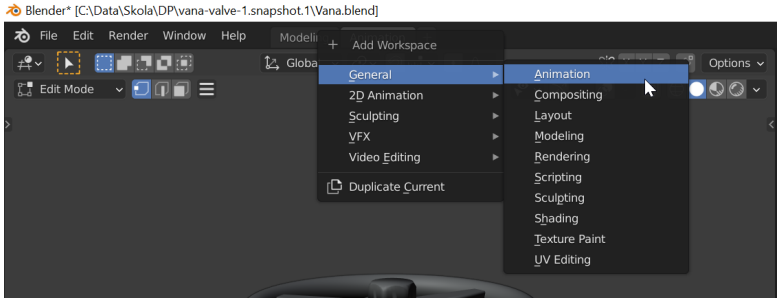


Figure 5.1.29: Blender - workspace context menu

- The animation workspace provides a preview of the animation on the left, the timeline is placed on the bottom and all the tools to move or change the object state are on the right with the scene collection (items of the project, camera settings, etc.) and corresponding preview.

[5] https://www.blender.org/

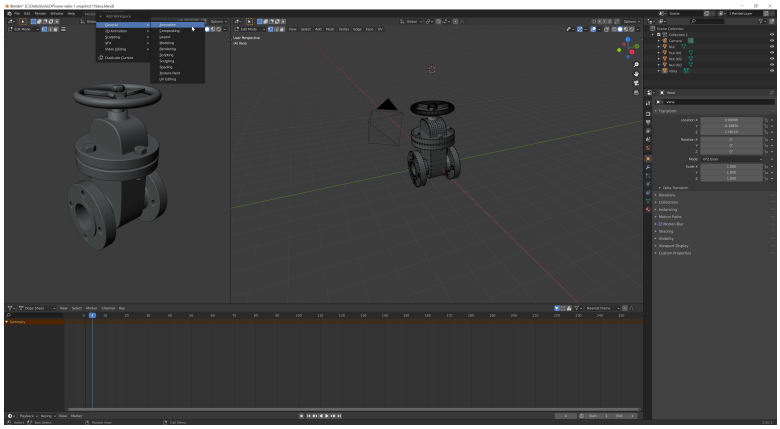
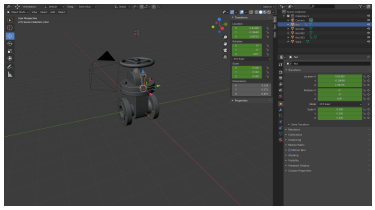
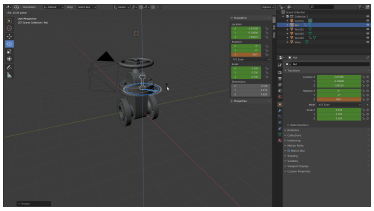


Figure 5.1.30: Blender - animation workspace

- Now it is time to select an object to be animated, change its state, and then select a time point at the timeline or vice versa. In our case, first, we will select an item to be animated. This is done by simply clicking on the item or selecting it from the explorer. The movement can be done in a very similar way to the predecessors. From the transformation menu on the left, we can select a type of transformation and by inserting precise values or just dragging the axis sliders we achieve the transformation.



(a) : Location controls



(b) : Rotation controls

Figure 5.1.31: Blender - object transformation

- To capture the state of an object at a certain time we again use keyframes. All the necessary controls can be found at the bottom next to the timeline. As in already covered software, there are two options of keyframe setting, manual and automatic. We are focusing on the manual one which can be done simply by pressing I key on the keyboard when a certain time and object selected or it can be done via the button in the corresponding context menu.

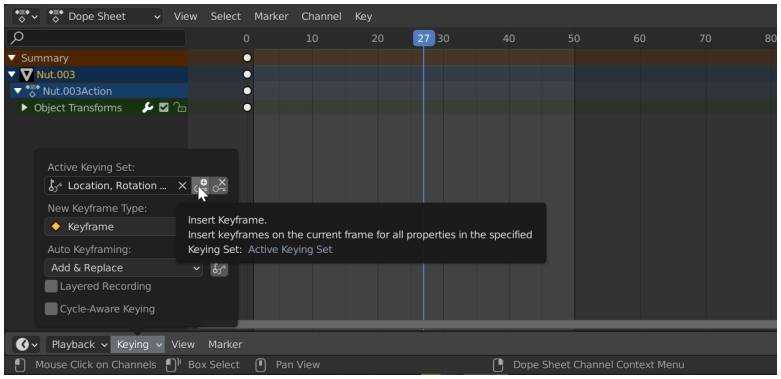


Figure 5.1.32: Blender - keying setup, insert keyframe

- This way we create an animation that is visible on the timeline with its keyframes and other properties only when the object is selected. The animation can be further adjusted, viewed, deleted, etc. The corresponding context menu pops up when clicking on the Key button.

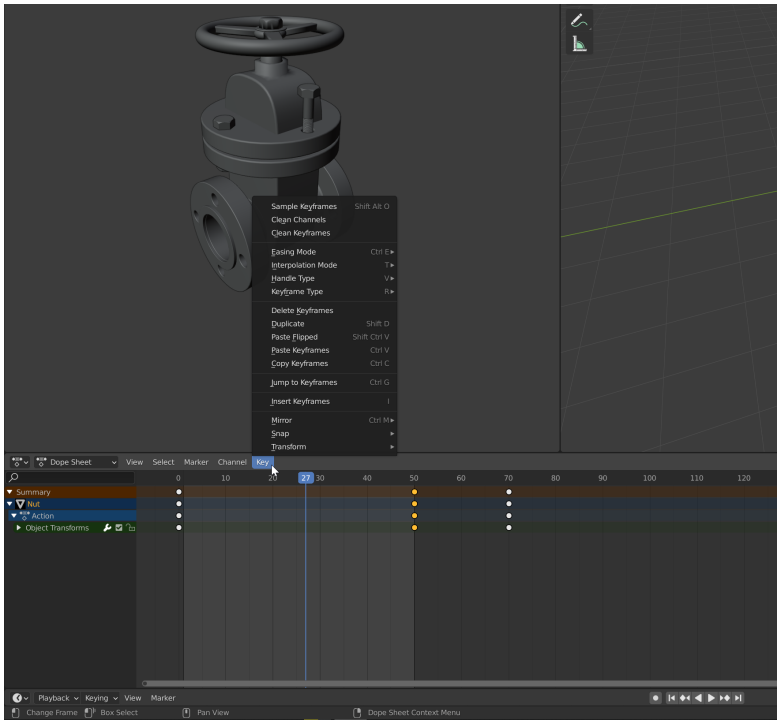


Figure 5.1.33: Blender - key editing context menu

- For more advanced adjustments the Blender offers an F-Curve view of the timeline where the movement timespan and more other features can be edited.

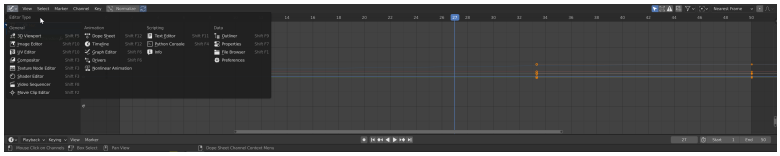


Figure 5.1.34: Blender - advanced view options (F-Curve view)

5.1.6 Houdini 18.5

Another very capable software is called Houdini[6]. It builds on procedural techniques for creating geometry and models to work efficiently. The software is more focused on visual effects so again for our purpose we will just slightly touch its capabilities.

Animation Creation

When we open the software and import a project we can see most of the tools needed for our purposes. The main thing on the screen is our model view, on the left side we have all controls for movement and transformation, and at the bottom, there is the timeline. We leave out the tools on top since they are mostly used for model creation. On the right side, there are the control fields for more precise transformation, and lower we can see our model file/item structure.

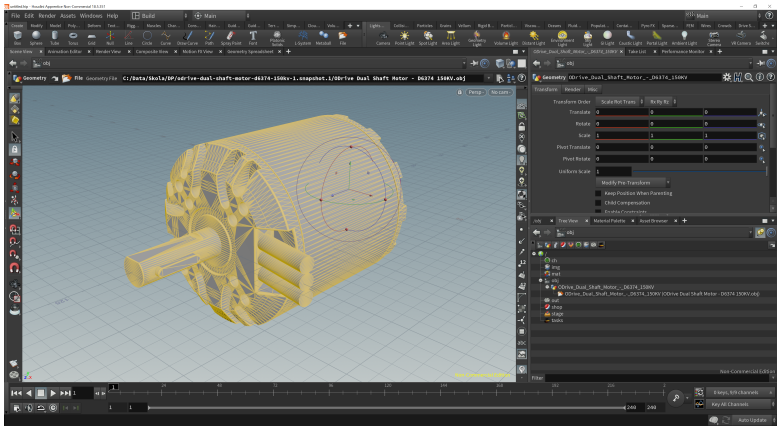


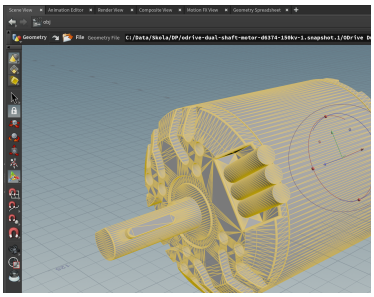
Figure 5.1.35: Houdini 18.5 - user interface preview

- The process of creating the animation is analogous to previously reviewed software. By moving with the timeline slider and selecting a point we choose a certain point in the time.

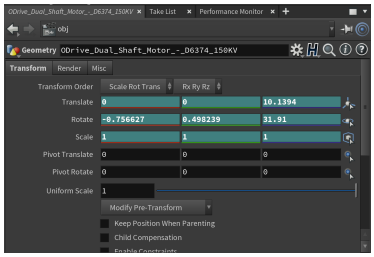
Figure 5.1.36: Houdini 18.5 - timeline

[6] https://www.sidefx.com/products/houdini/

- When a time point is selected we need to transform our object to a state we want the object at that time. This is done via the tools on the left toolbar. We can choose from Move, Rotate, Scale, etc. The transformation is then applied by dragging the corresponding axis, or rotation slider, or it can be more precisely set at the transform tab on the right with input fields for all necessary values.



(a) : Transformation controls



(b) : Transformation input fields

Figure 5.1.37: Houdini 18.5 - object transformation

- To capture a state of an object at a certain time we as usual use the keyframes. By simply clicking on the key icon button, we set a keyframe. Using the keyframe context menu which brings up more options we can also enable the already known automatic keying option.

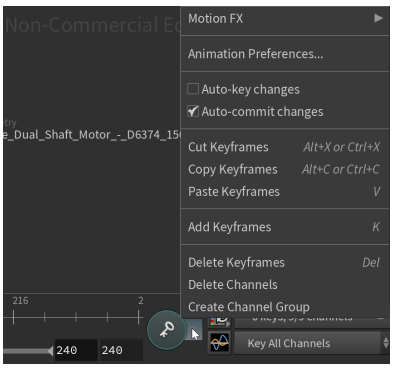
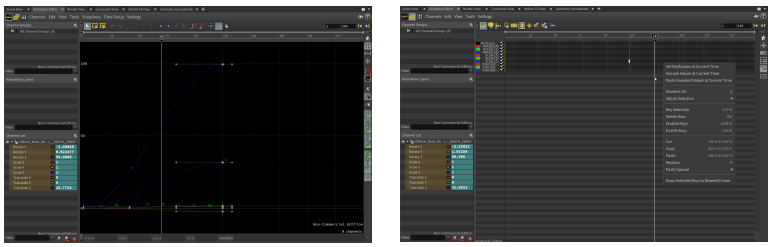


Figure 5.1.38: Houdini 18.5 - keyframe context menu

- To make it easy to further edit the animation we have already created the Houdini provides Animation Editor. This can be brought up by clicking on the corresponding button in the bottom-right corner. Or the better way is to directly change the workspace to the Animation Editor on the tabs below the top toolbar. This workspace provides an already known F-Curve view on the animation process or the more simple Channel Groups view on each movement/transformation and its keyframes. These views offer a nice and simplified way to select, edit, or even delete each keyframe.



(a) : F-Curve **(b) :** Channel Groups

Figure 5.1.39: Houdini 18.5 - advanced timeline views

5.1.7 Clara.io

The only application that is cloud-based and runs in a web browser is the Clara.io[7]. This means that no setup and installation on the user's local machine is necessary. The only thing you need is a web browser and with some limitations, the application is free to use. It provides powerful 3D modeling and rendering tools that are easy to use coupled with many sample models available to work on.

Animation Creation

The startup window can have many different layouts as in all other software mentioned before and we will start with the layout shown below. The application does not have any specific animation workspace as opposed to other analyzed software. On the left, we have the explorer listing all elements in our project. The top toolbar consists of tools to transform the object, create an object, add lightning, etc. The timeline is again on the bottom and on the right we have detailed settings for a selected feature.

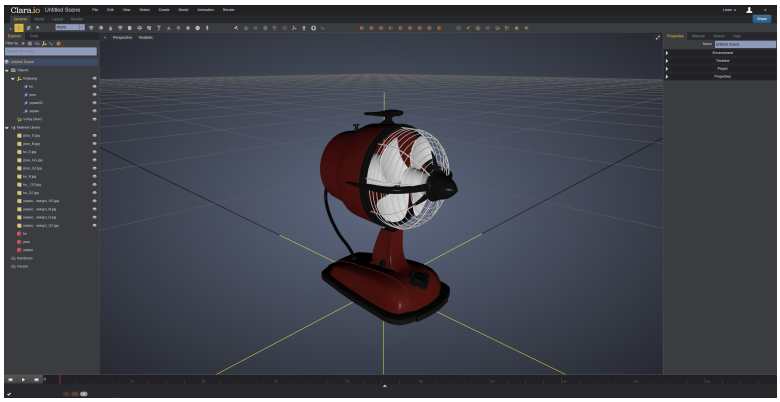


Figure 5.1.40: Clara.io - user interface preview

- The first step in animation creation is to select an object to be animated. This can be done in multiple ways, simply selecting the object from the

[7] https://clara.io/

explorer or clicking on the object itself in the 3D scene. The object is then nicely highlighted in the explorer as well as in the scene.

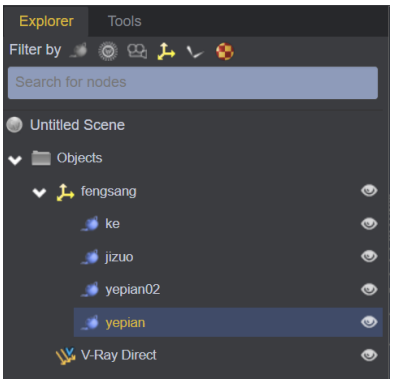


Figure 5.1.41: Clara.io - scene objects explorer

- The transformation of the selected object is then done by tools located in the top-left corner of the window.

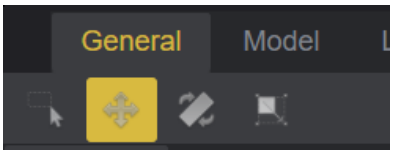
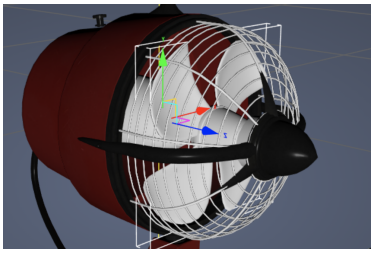
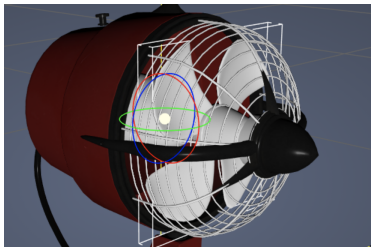


Figure 5.1.42: Clara.io - selection/transformation toolbar

When a tool is selected we can see the corresponding axis controls. We can simply move/transform the object by dragging these. To create a more precise movement we have the option to add precise values on the right side of the window in the Transform tab.



(a) : Position controls



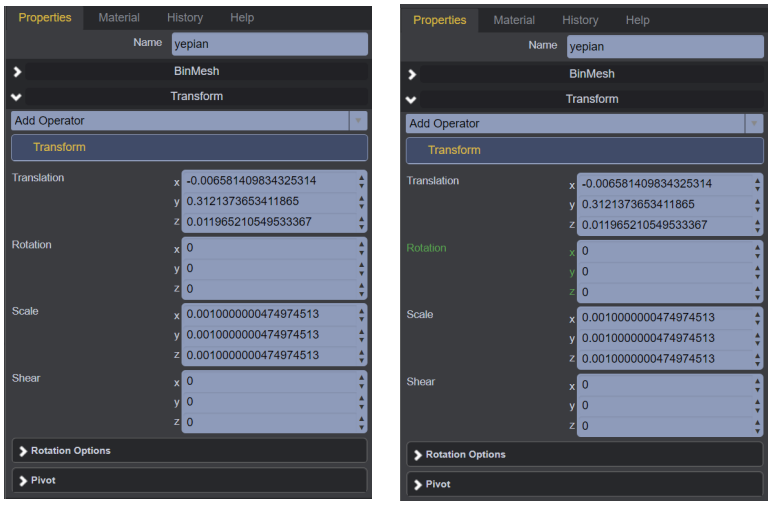
(b) : Rotation controls

Figure 5.1.43: Clara.io - object transformation controls

- The timeline at the bottom is then used to set a time point at which we want to capture the state of the object.

Figure 5.1.44: Clara.io - timeline

To capture a state we need to create a keyframe. In this case, it is done in a completely different way than in the other software reviewed. The keyframe is set by clicking on a specific transformation label that should be captured, the keyframe then appears on the timeline, and the label we clicked on changes color (the process is illustrated below for initial rotation keyframe).



(a) : No keyframe **(b) :** Keyframe set (rotation)

Figure 5.1.45: Clara.io - setting a keyframe for rotation

- The timeline now consists of keyframes, furthermore, we can view their information by moving a cursor on top of them.

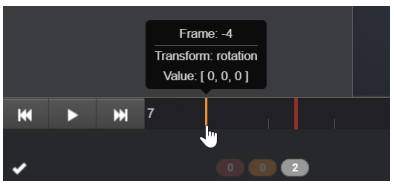


Figure 5.1.46: Clara.io - keyframe information

The keyframes can be moved and the transformation can be edited (when a keyframe is selected) with the Transform tab fields on the right, which also, show the change in each value throughout the time when previewing the animation.

5.2 Misterine Studio Analysis

First, we will focus on the analysis of the Misterine Studio and its user interface. Throughout the analysis, we mostly pay attention to 3D model manipulation in particular to the 3D scene workspace (formerly called Scene) of the studio. But the Process scheme workspace (formerly called Creator) will be analyzed as well to make a better sense of the goals we are trying to achieve with the application. Even though the Process scheme workspace analysis outcomes will not be of our main focus during the low-fidelity prototyping stage, the outcomes will be used in the later stage of the high-fidelity prototyping where the workspaces will be bound together to create the whole application. During the analysis, we compare the implementation with our findings from the state-of-the-art software analysis as well as from the usability research and make brief suggestions on Misterine Studio design improvements. The overall design is then concluded in the following section.

5.2.1 The Process Scheme Creation

When we open the Misterine Studio the initial window is empty. By accessing the top menu and clicking on File and New project we create a project where a process scheme for our user guide can be created. The picture below is illustrating the window overview when a process scheme is already created to show all its components.

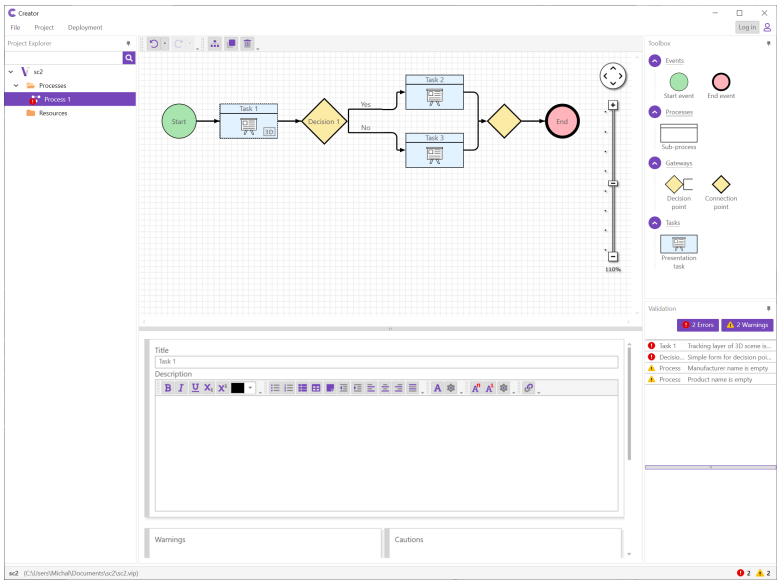
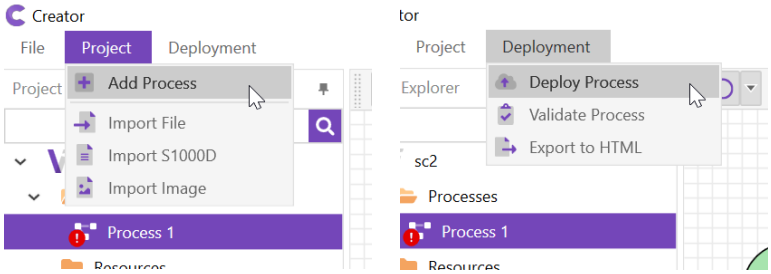


Figure 5.2.1: The Process scheme workspace overview

First, we will focus on the top menu. In the File submenu, a user can expect usual functions such as create a new project, open a project, save project as, etc. Moving on to the Project submenu which contains the process addition option as well as other attachment file import options. Last, is the

Deployment submenu which is used for deployment of the process at the end of the work, and also an important feature of process validation is located here, together with HTML export of the process. The validation feature checks for all unfinished processes and tasks to prevent any later errors, such as processes without end nodes, or disconnected nodes in the process. The general design of the menu and its controls are implemented well from the user perspective and usability principles, but the naming of its submenus does not clearly reflect its content. Mainly the naming of the Project submenu would be more suitable to name Process submenu since it encloses functions relevant to processes of a project.

Problem 1 (Naming). The naming of components, menus, and functions should be picked wisely and should reflect the function's purpose, or the menu's content as much as possible.



(a) : Project **(b) :** Deployment

Figure 5.2.2: The Process scheme workspace top menu options

When a user clicks the Add process the initial process scheme is added and we simply use the provided toolbox on the right side to create our desired process scheme out of its components, consisting of start and end node, decision nodes, and task node. There are two options for how to add these components to the scheme. One is by simply dragging them to the scheme pane or by selecting one of the components in the toolbox and then clicking on the desired position in the pane. The last thing is to connect each node with connectors as needed using the connection points of each component, or node.

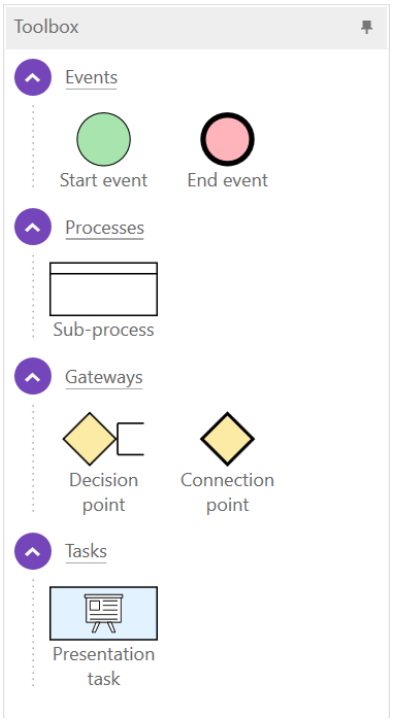


Figure 5.2.3: The Process scheme workspace toolbox

Throughout the work, we can create multiple processes as the content of one project. These processes, as well as other resources such as images or any other files linked to the project, can be accessed and organized using the Project explorer on the left side of the workspace. The explorer also provides a search option for quicker orientation in larger projects. The file hierarchy visualization and implementation of the explorer is definitely a good practice generally used in all similar software. The problem of the current implementation is that a user can add multiple processes to the project while there is no indication of what process is being presented in the pane to the user.

Problem 2 (State indication)**.** The user has to be always informed about the state he is currently in. Such indication of the current state or indication of the object currently shown is crucial for user experience.

The problem is further enforced since the user can select (highlight) another process in the explorer and not open it in the process scheme pane which causes even more confusion. Using some kind of labeling on top of the process scheme pane is essential in this case to see what process is being presented.

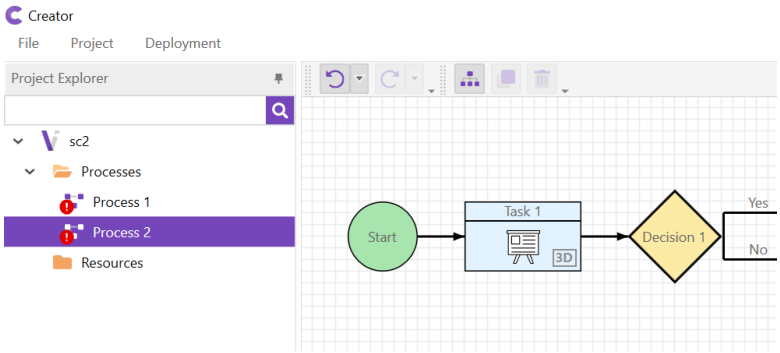


Figure 5.2.4: Presented process scheme confusion illustration (Process 1 is presented in the pane while Process 2 is selected in the explorer)

Textual description, other safety requirements can be added to each process and even more in the description component below the process scheme pane. Moreover the same applies to each presentation task of a process scheme. A user can set its title, description, or other references, warnings, cautions, etc. to provide the information not only to the final user of the AR technical documentation but also for the graphic designer that will work on the 3D scene creation. As was already indicated the 3D scene can be added to each task, which creation we will analyze in a detail later. The corresponding fields are located on the bottom of the workspace below the process scheme pane. The 3D scene can be added to each task using the context menu by right-clicking the task's node. Tasks already having the 3D scene set are labeled with "3D" which nicely helps a user to quickly distinguish the tasks.

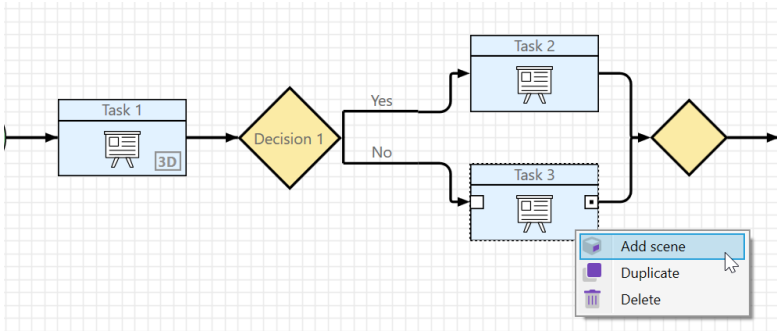


Figure 5.2.5: Adding 3D scene to a task

5.2.2 The 3D Scene Creation

The 3D scene creation begins by opening a new window, the 3D scene workspace. This separation of the workspaces into two separate windows does not follow the rule of minimizing the window management and increases the cognitive load on the user.

Problem 3 (Window management)**.** The window management should be always minimized to lower the cognitive demand on the user. Using tabs, or

parallel panes for the separation of workspaces would satisfy both needs (the separation as well as the low cognitive load on the user).

Therefore when binding the two workspaces together at the stage of high-fidelity prototyping we will strive to deal with this inconvenience.

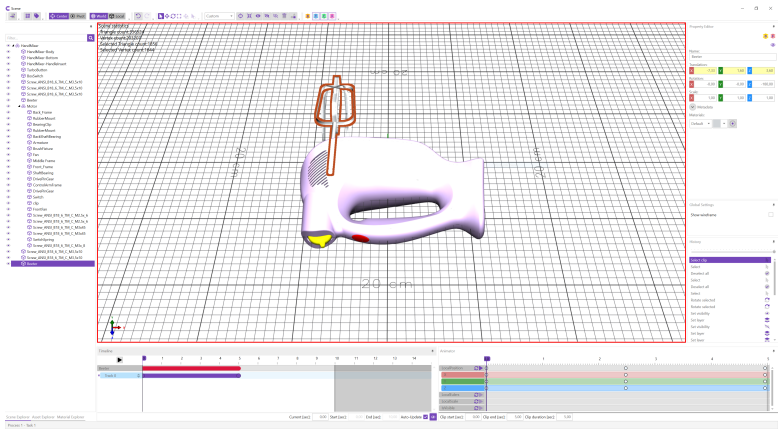


Figure 5.2.6: The 3D scene workspace overview

Starting with the import of a CAD file containing a 3D model we add the model to the task of the process. This is done using the top toolbar as well as many other basic operations such as tracking marker and labels addition, coordinates selection, positioning, or transformation, visualizing the object, and visible layer selection.

Figure 5.2.7: The 3D scene workspace top toolbar

3D Model Manipulation

When having the 3D model imported the foreground layer is disabled and only the contour of the model is visible. This is not the right behavior and it would definitely improve the user experience to see the model clearly in the pane when imported.

Problem 4 (3D model import behavior)**.** The 3D model should be visible with all its components when imported from a CAD file. This gives the user immediate feedback on the 3D model import and endorses the workflow.

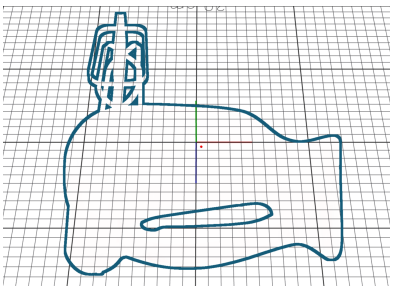


Figure 5.2.8: The 3D object contour when CAD file imported

The whole 3D model with each component can be seen in the explorer on the left side. The explorer implements logical hierarchy and organization of the items imported. Using the explorer we are also able to select a specific object or multiple objects for further manipulation. On top of the explorer, the search field is provided through which a user can filter out certain items. This feature very well extends the usability of the explorer itself but it has several shortcomings. There are certain filter expressions (shortcuts) that can be used to for example filter out only animated objects, but these expressions need to be memorized by the user.

Problem 5 (Explorer filter expressions)**.** The filtering options in form of expressions are a crucial drawback to the very useful feature of content filtering. Memorization demand on users should be minimized and therefore using for example buttons implementing major filter expressions could be a very effective way to achieve that.

By selecting the object in the explorer or directly by clicking on it in the 3D scene pane the Property editor on the right side gets enabled. The object's parameters such as position, visibility, etc. are accessible throughout this component's fields. To set the object to be visible it is necessary to toggle the foreground layer icon.

Now it is time to position the object and set the view we want. The main toolbar provides a preset view to simplify the positioning of the model view. This is a very useful and valuable feature when the user is not that comfortable viewing the object using the mouse controller, or even for quick orientation of the view. To get a custom view we use the mouse, by holding the right button and moving we change the view angle, by scrolling on the mouse we zoom in or out of the view. The top toolbar also provides centering the selected object on the 3D scene pane, hiding it, etc.

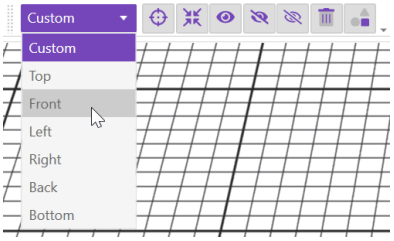


Figure 5.2.9: The 3D scene workspace - model view options

To change the properties of a selected object, or objects, the aforementioned Property editor is used. This way we can also precisely transform the object, or change its visibility layer.

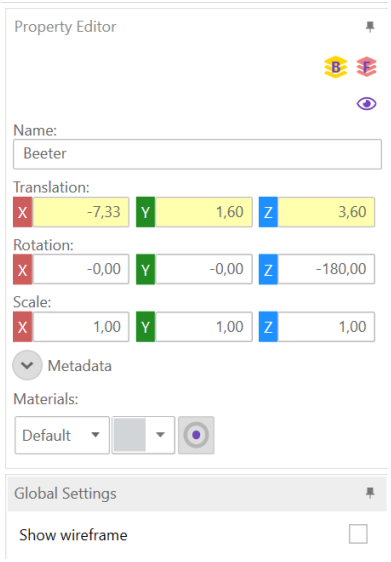


Figure 5.2.10: The 3D scene workspace - Property editor

The previously mentioned transformation can be also done with the controls provided on the top toolbar. Choosing one of the options (translation, rotation, or scale) we enable the transformation controls that are shown directly alongside the object in the 3D scene. These controls can be dragged while the transformation is immediately visualized. On the illustration below the translation controls are visible, the scale controls work analogously, and the rotation controls follow the already known design of circular sliders from state-of-the-art software analysis.

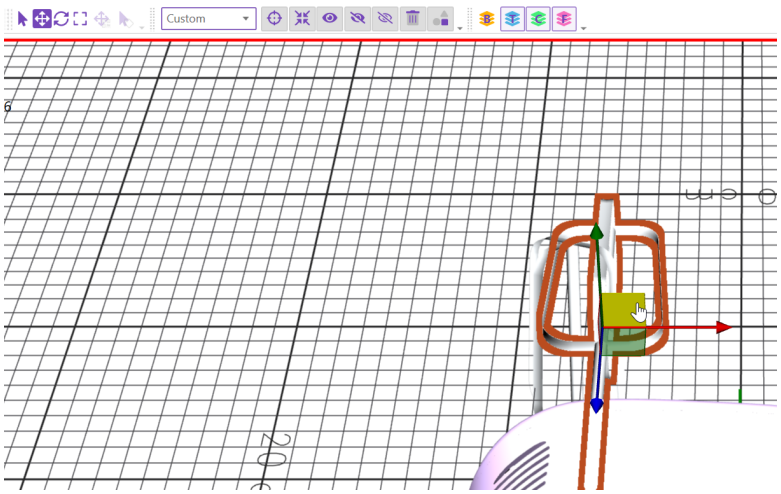


Figure 5.2.11: The 3D scene workspace - transformation controls (translation)

The design of the toolbar, Property editor, and transformation controls is created well. To even more improve its usability and accessibility the implementation of logical keyboard shortcuts and meta-key for frequently used functions is crucial.

Problem 6 (Keyboard shortcuts layout)**.** Logical and understandable keyboard shortcuts and meta-keys layout is essential when it comes to workflow effectiveness and daily use of such software.

From the usability perspective tooltips or even extended help options on certain tools would help the novice or less frequent users to learn the concept quicker.

Problem 7 (Labeling and tooltips)**.** Hinting is a form of a tooltip further extends the problem of State indication. Telling the user what can be done in a certain state, with a certain tool, or even when a meta-key is pressed enforces the correct way of workflow and improves the user experience (not just for novice users). Moreover labeling objects with special functions or parameters is essential for their recognition.

Object Animation

The 3D scene workspace consists of Timeline and Animator components located at the bottom of the main window. This is the part where most of the animation controls are placed. The Timeline takes care of visualization and manipulation with several animation tracks for a certain object. These tracks are then split into clips which we can refer to as a single simple animation of an object. Each clip's duration can be modified directly in the Timeline by dragging its ends, or its position on the timeline can be changed as well. For further animation clip modifications, the Animator is used. In the case of the preset animation, the Animator component simply shows several input fields and/or toggles that are used to set the animation parameters. When a custom animation is used the Animator changes into the more advanced mode when it is displaying precise animation keyframes. This way a user can create any desired animation in the same manner as in most animation software.

The first step when creating a custom animation is to position and select the object we want to animate. Doing so we enable the timeline, and by clicking the create animation component button we add animation to the object, specifically a new animation track is added to the timeline with one animation clip. Furthermore, at the bottom of the Timeline component, the timeline parameters are visible all the time when an animation track is present which is a good design practice. The user can nicely see when the track begins or ends, etc.

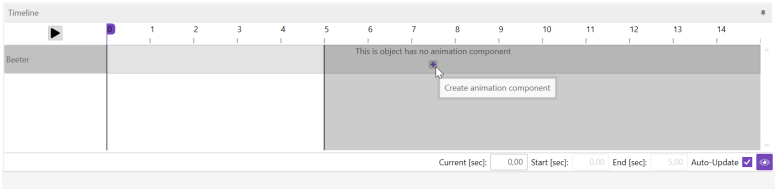


Figure 5.2.12: The 3D scene workspace - timeline (add animation)

As was already mentioned, the animation track is formed of several clips (representing partial animations) which are then visible as colored bars in the timeline. The clip bars function as a slider, by dragging the ends we can extend or shorten the duration of the clip or we can change the position of the clip in time by dragging the whole clip.

Problem 8 (Tracks and clips)**.** From the use case point of view (emphasis on preset animation, or a quite simple custom animation creation) and the ease of understanding the animation process, the animation track and animation clips hierarchy could be simplified. We are able to achieve the same result with only the animation track representing, or having one animation clip. These "simple" tracks could be then organized in the timeline and further edited.

To create a preset animation an animation generator can be used. By right-clicking on the clip we bring up the context menu where the generator is located with several preset animation options. Unfortunately, these options are quite hidden and hard to find for a novice user. Using this right-click context menu the clip can be also revered, saved for later use, deleted, etc. Other important but fairly hidden features of the context menu called End wrap consisting of four options Stretch, Clip, Repeat, Ping-pong are used to set the behavior of extension or shortage of the animation clips. Using the stretch option rescales the keyframes accordingly to a new length of the animation clip. Contrary to this option, the option clip preserves the position of each keyframe and cuts out or extends the time of the animation clip. The repeat and ping-pong options are just variations. While the repeat option is enabled the extension of the animation clip results in repeating the clip for an extended time, on the other hand, the ping-pong option also reverses the animation clip to go forward and back when extended.

Problem 9 (Hidden features)**.** Hidden features are one of the biggest drawbacks of the Timeline/Animator design. Mainly the most essential and frequently used features, tools, and controls need to be directly accessible from the main UI layout and visible whenever they can be used.

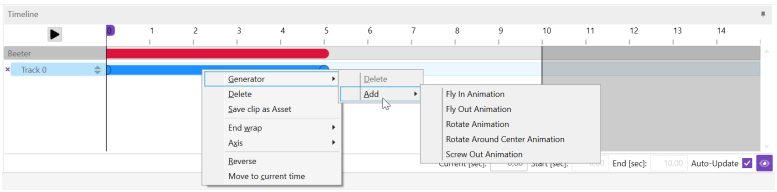


Figure 5.2.13: The 3D scene workspace - timeline (clip context menu)

Choosing one of the animation generation options displays the input fields for corresponding animation parameters in the Animator component for the animation generation. Again at the bottom of the Animator, the corresponding time properties are shown along with the advanced option which can be used to view the generated keyframes.

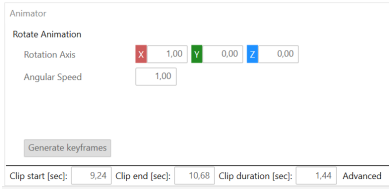


Figure 5.2.14: The 3D scene workspace - animator (preset animation parameters)

The second option is to create a custom animation. Using the time slider on the timeline we choose a time point in our animation clip. Then by applying a transformation to the animated object we create keyframes that are visualized in the animator. The Misterine Studio uses auto-keying so the object transformation change is recorded at any time. But the user has the option to set explicitly a keyframe using the K key on the keyboard. The animation process follows the same principle applied in the state-of-the-art software but the auto-keying option can not be turned off and the implementation of the manual keying is a bit confusing, while a visible set key button is completely missing.

Problem 10 (Auto/manual keying)**.** The user should be able to explicitly choose between the auto-keying and manual keying options. Also when the manual keying is turned on, the keyboard shortcut to set key and a button such as "Set key" should be provided to the user.

Later on, the keyframes can be dragged to a different time point, the object state can be modified when a key or keys are selected, or the user can completely delete the keyframe using its right-click context menu. The key context menu does not offer functions such as for example the go-to previous/next key function we know from the SOA analysis.

Problem 11 (Keyframe context menu)**.** Options, functions such as go-to previous or next key are missing in the key context menu. Providing the user with more options would improve the workflow and the work effectiveness.

For more advanced users, and more complicated animation creation the lack of feature often called F-curve editor or just curve editor could be another

downside of the existing design, but due to our use-case of a rather simple animation creation, these are no of our main concerns. Other than that the key manipulation is handled well to the standards.

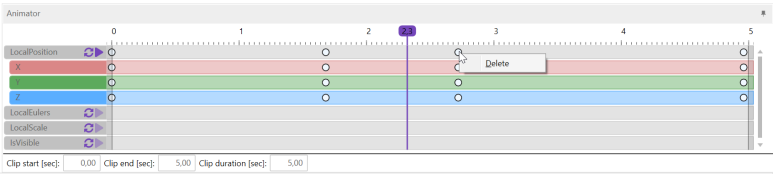


Figure 5.2.15: The 3D scene workspace - animator (keyframe preview)

To playback the animation we use the play button at the top-left corner of the timeline or we can preview separate animation clips in the animator. At the end of the work on the animation, we close the 3D scene workspace which saves the scene to a corresponding task. We can get back to it later again by opening the scene of the specific task in the Process scheme workspace.

5.3 UI Analysis Conclusion

Most of the SOA software used for 3D modeling, animation, and simulation has a lot more to offer than what are our needs and what we are able to cover in this analysis. From a user perspective, ease of use, and learning curve, the Fusion 360 and Clara.io, and their really simple and well-arranged user interface make them stand out from the others. But this is certainly biased by the fact that the other software used has many more design capabilities to offer. In our case, we focus mainly on simple 3D object manipulations such as translation, rotation, scaling, and visibility changes, and their animation. Therefore we strive to design an appropriate UI and focus on providing good UX while creating AR technical documentation. From the SOA software research, we might see that the tools have many similarities in how to handle certain operations, how the workspaces are laid out, etc. These similarities are essential to be followed in the new designs to preserve a good UX for those users familiar with such software. Most of the features are implemented in the way the literature suggests and correspond to our theoretical findings.

During both parts of the software analysis, we had the same working procedure as well as the same goal to make the comparison of different UI design approaches unambiguous and feasible. Unfortunately, the incompatibility of the 3D model file format and the 3D modeling/animation software did not permit the use of the same 3D model in certain cases. Even so, the same goal and the working procedure were followed with emphasis on work efficiency and user experience.

An existing Misterine studios UI design has some shortcomings to fulfill our needs as well as to fit the criteria for a good UI/UX design advised by the literature [9][10]. The following paragraphs depict each of the studio's design drawbacks with suggestions for improvement.

Starting with the visual aspect, mainly the layout of the UI, the workspace implementation which divides the workflow into two separate parts, the Process scheme workspace and the 3D scene workspace, obey the usability principles. The shortcoming of the existing implementation is opening another window for the 3D scene workspace. This implementation goes against the navigation practices, especially the minimization of window management demand on the user (Problem 3). Moreover, all the software analyzed before is a good example of handling this problem using multiple tabs in one window or generally replacing the content of the window with requested workspace features.

Furthermore, the 3D scene workspace and its scene view provide just one viewpoint on the 3D object at a time. Even though some of the SOA software did not have 4-pane viewpoints implemented as well, it would be suitable to give the user the possibility to use it in our design.

Problem 12 (4-pane viewpoints)**.** As the research shows it is convenient to use multiple, usually 4-pane viewpoints for an effective workflow while also reducing cognitive demand on users.

Maybe one of the most significant drawbacks and major usability problems are the so-called hidden features in the existing design (Problem 9). This shortcoming can be illustrated on the animation track addition which is only accessible by right-click context menu on the timeline or the hidden animation preset options. The problem can be further enlarged when the UI does not implement effective tooltips that enhance the understanding of the tools and controls which is critical mainly for less advanced users (Problem 7).

Moreover, an indication of state, and especially indication of a file, process, the user is working on is crucial from the usability perspective. The user has to be always visually informed on what is happening, on what file he is working on, etc. (Problem 2). This issue can be seen in the Process scheme workspace, where there is no indication of what process scheme is being displayed at the time.

The next fundamental issue is accessibility. Current Misterine Studio lacks keyboard accessibility and well-designed meta-keys for extended functionality as well as keyboard shortcut layout for more effective workflow (Problem 6). Following the issue, the mouse controls currently implemented differs a lot among the software. The key would be to gather similarities and propose a consistent controls layout. Features such as position fine-tuning when using the mouse, or the auto-scroll when dragging an item out of the range need to be implemented as well for better user control and satisfaction as addressed in the previous section.

Problem 13 (Fine-tuning)**.** Implementation of transformation, or generally object manipulation fine-tuning (auto-scroll, discrete snapping, etc.) when using a mouse controller is essential for usability and improves the user experience while working with such software.

Last but not least is the animation timeline simplification. Since the animation tasks resulting from the use case scenarios are not that complicated

as some of the animation and simulation tasks that can be achieved by the more sophisticated SOA tools, there is no need for the division of an object animation into tracks and clips which can be as well a bit confusing for the user (Problem 8). This issue will be closely discussed in the following part of low-fidelity prototyping.

On the other hand, the present design already implements well-designed cursor hinting, so the user is informed of the actions available. Unfortunately due to the ongoing developement of the Misterine studio, not all the hinting work well yet. This is followed by suitable item manipulation and selection techniques that correspond to best usability practices. The project explorer implementing reasonable hierarchy and overall component layout and tool grouping is consistent and logical. The design also strives to minimize dialog boxes which is always beneficial when it comes to usability and user satisfaction.

As throughout the whole thesis, our main focus is the 3D scene workspace and animation. In the following chapter, we take these outcomes into the account and design a low-fidelity prototype of the UI for the 3D scene workspace. Later on, we will conclude the design and define more advanced feature requirements from which we create the high-fidelity prototype. At this last stage, we will also take the Process scheme workspace into the account and bind the workspaces, their functions, and controls together to create the whole application.

Part II

Low-Fidelity Prototyping

Chapter 6

Low-Fidelity Prototype

The aim is to create an understandable and productive UI with usability as one of the main aspects. Throughout this chapter, the low fidelity prototype of the UI for 3D model visualization, manipulation, and animation (3D scene workspace) is introduced based on the findings of the current UI/UX practices and market analysis. The whole prototype is created using Balsamiq Wireframes[1] tools and attached to the thesis. The interconnection with the whole studio, mainly the Process scheme workspace, and also its UI design, is addressed in the stage of the high-fidelity prototype design.

6.1 Overview

The main window arrangement did not undercome many changes when developing the prototype. Starting from the top-left corner we have the main menu providing file operations such as import CAD model. Below, the toolbar is located where the user can locate all the tools, marker or label addition, visible layers selection, coordinate settings, object manipulation or undo and redo options. On the left side, we have a Scene explorer that provides logical grouping and easy orientation for all 3D scene items available, such as 3D model parts, furthermore, the explorer is divided into several tabs as in the existing design to store and organize assets and materials that are used in the 3D scene as well. The 3D model is visualized on the middle pane (3D scene) where it can be manipulated, the important UI component to mention here is the cube providing preset viewpoints of the 3D model in the top-right corner. This component basically provides the same function as the dropdown select list in the existing design to set a preset view of the model. The right side hosts the Property editor with precise transformation input fields as well as visibility layer toggles. Below, the Animation explorer is provided for quick access to the animation controls and the animation addition alongside with History component for a preview of already executed work steps. On the bottom of the window, the Timeline is placed together with the Animator. The Timeline visualizes all the animation tracks available for the selected object with the Animator showing details of the track selected in a form of

[1] https://balsamiq.com/wireframes/

keyframes (or showing the input fields to set the preset animation parameters). The whole concept is illustrated in the picture below. Each component will be closely described in the following sections of this chapter.

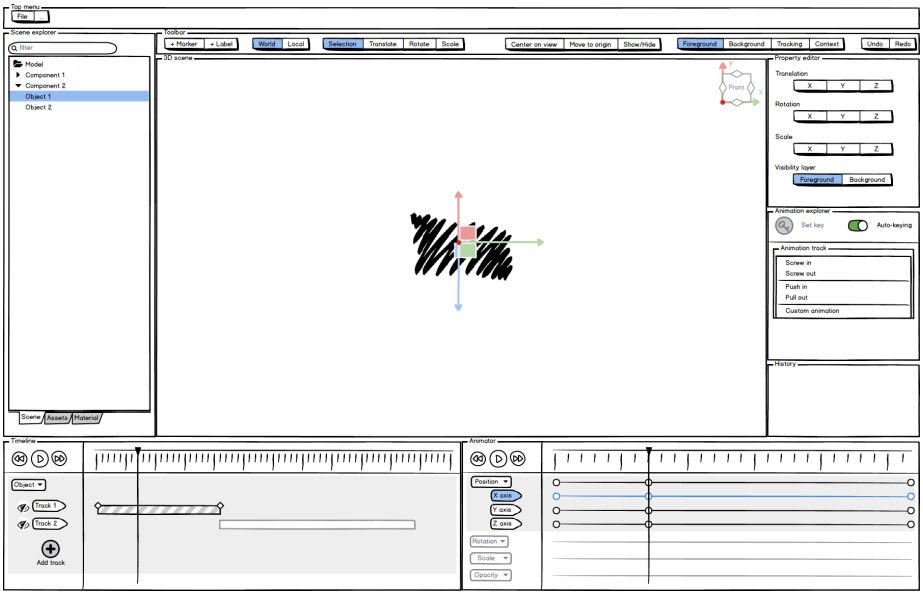


Figure 6.1.1: Low-fidelity prototype - overview

6.2 Toolbar

The toolbar should incorporate all the most necessary tools used regularly for most of the operations during the workflow. Starting on the left we have the add tracking marker button (used mostly at the end of the scene creation), and the add label button which provides labeling for a selected object as an additional feature to keep track of the objects in the scene. Following buttons provide coordinate system change. Further, the object selection or transformation tools are placed. The other controls should be available just when an object is selected and are used for positioning in the 3D scene, or hiding objects. Next, the tools for the selection of visible layers are available. While the foreground layer is the one that is getting visualized in the final AR user guide. The last two controls are quite self-explanatory but to make it complete these are used to undo or redo any action. Using all these controls we can modify the 3D scene view, transform an object, change the coordinate system, and so on.

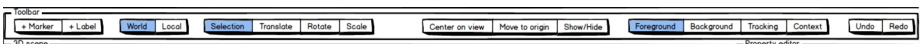


Figure 6.2.1: Low-fidelity prototype - Toolbar

6.3 Scene Explorer

All the items available for a 3D scene are hierarchically organized in the explorer. The explorer is quite a simple component so we are not describing it in the detail. The main usability feature here that needs to be pointed out is that the selected object always needs to be highlighted in the explorer as well as in the scene and vice versa. Moreover, the Scene explorer is divided into tabs to separate the 3D model items and the assets such as other additional models saved animations, etc., or materials that can be used in the 3D scene creation as well. On the illustration below we can see a scene explorer with the Scene tab active where Object 1 of Component 2 is selected at the time (refers to the State indication problem).

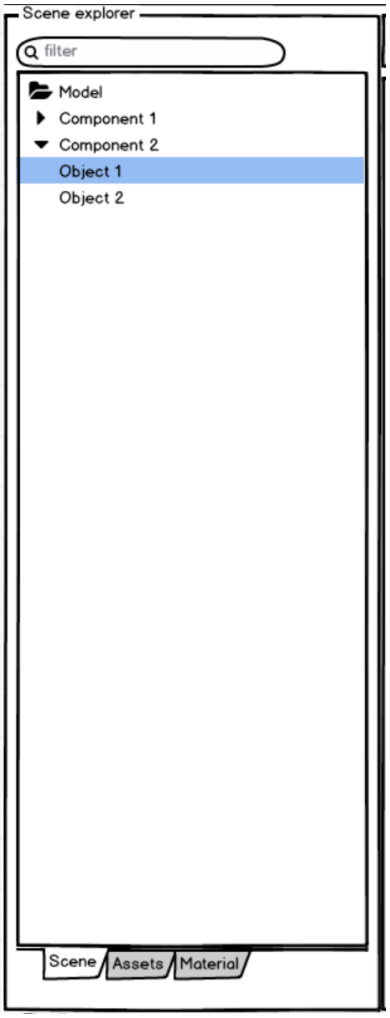


Figure 6.3.1: Low-fidelity prototype - Scene explorer

6.4 3D Scene

The 3D scene visualizes our 3D model and all the manipulation with it and its transformation takes place here. There are almost no changes to this design from the already existing one. The object transformation controls in a form of axle arrows for translation or circular sliders for rotation in each axis stay the same. The main difference is the feature providing preset viewpoints of the scene, the preset view cube in the top-right corner of the pane. When clicking one of the diamonds on the edges, the cube rotates as well as the 3D model view changes accordingly. This provides the user with a quick and easy orientation of the model in the 3D space and an immediate sensation of the action.

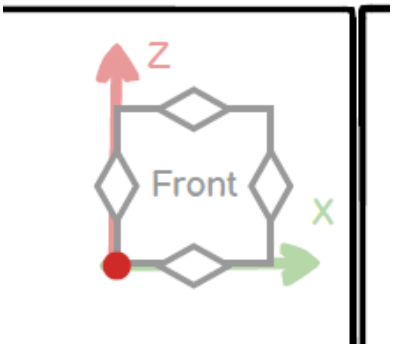


Figure 6.4.1: Low-fidelity prototype - preset viewpoints

6.5 Property Editor

When an object is selected the Property editor input fields get available. The object then can be manipulated with the tools accessible from the main toolbar but the other option is to use more precise input using the Property editor's input fields. The coordinate fields are showing the precise translation, rotation, and scale of the object. At this component, we also change the visibility of the object in the final AR output. Important to note here is the fact that the illustrated input fields correspond to a selected object from a 3D model and depend on the type of object selected. Some more sophisticated objects can have even more input fields, such as for example material selection. Furthermore, if a user selects a tracking marker there are no scale fields available as well as the Tracking layer is the only available layer for this type of object. On the other hand for the tracking marker, we have input fields such as physical size or marker code available. Similar changes apply to the Label object for which the only available layers are the Context layer and Foreground layer and the translation fields are the only transformation fields available. These variations follow the existing design since they directly depend on the type and complexity of the object selected.

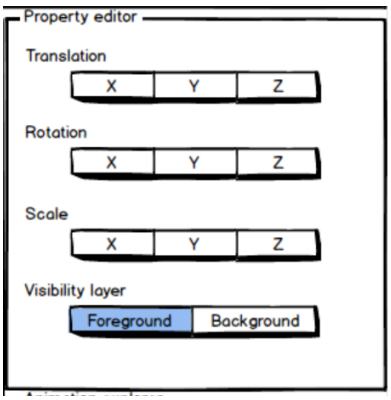


Figure 6.5.1: Low-fidelity prototype - Property editor

6.6 Animation Explorer

The main controls for animation creation are located in the Animation explorer component below the Property editor. By selecting an object its content gets enabled and the animation process can start. The keying options are analogous to the previously mentioned ones in the analysis part (refers to the Auto/manual keying problem). Below we have the options of generating a preset animation, which will first ask the user to set the animation properties in the Animator component, and then when the parameters are confirmed it autonomously generates the animation track with the corresponding animation. The second option is to create a custom animation track that provides the user with an empty animation track to create any animation he or she desires. All these options are directly available to the user overcoming the Hidden features problem.

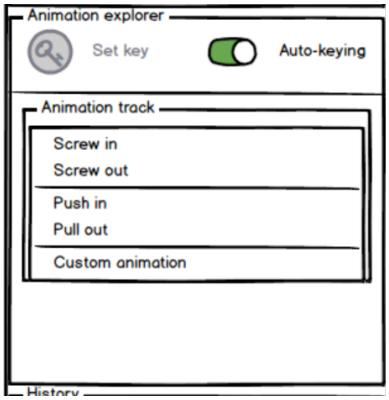


Figure 6.6.1: Low-fidelity prototype - Animation explorer

6.7 The Timeline and The Animator

The Timeline component is the place where the animation tracks are visualized and where we can edit them (the simplification proposed in Problem 8 is used).

The Animator is used for the track's keyframes visualization and editing, while it is also used as a parameter setting window for preset animation and further track editing.

When the user is adding a preset animation the parameters for the specific animation are set in the Animator. The animation track as a bar is then added to the timeline with the desired animation automatically generated based on the parameter setup.

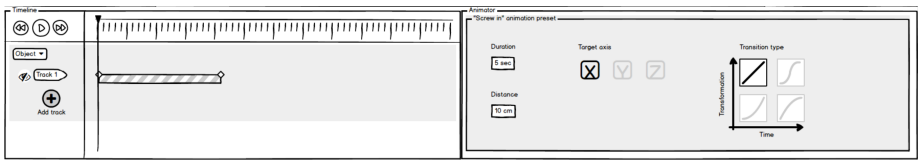


Figure 6.7.1: Low-fidelity prototype - preset animation

If the choice is to add a custom animation the track is added to the timeline with no keyframes at the animator resulting in an empty animation. The design follows proven practices from the SOA analysis and generally copies the existing design of the studio. When the auto-keying is enabled, the movement in time on the timeline followed by object transformation creates new keyframes at the selected time point and an animation is created. All the keyframes are visible in the Animator, where the user can further modify them.

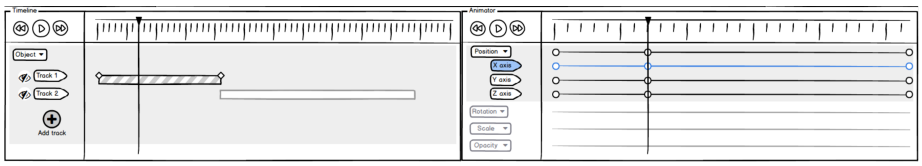
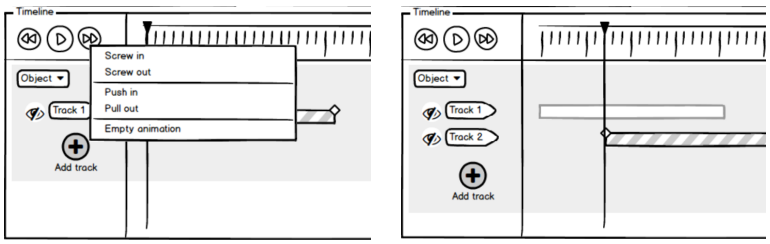


Figure 6.7.2: Low-fidelity prototype - custom animation

Adding another track is quite straightforward but there are two options. One of the options is using the already known options in the Animation explorer on the right. The second possibility is to click on the Add track button next in the Timeline frame. This brings up a context menu analogous to the Animation explorer options where a user can select the desired one.



(a) : Add track context menu **(b) :** New track added

Figure 6.7.3: Low-fidelity prototype - track addition

Diamonds at each end of the track's bar function as a dragging control, this way we can extend or shorten the track's duration. The shape of the dragging control is chosen with respect to accuracy so the user can clearly see where the track starts and ends. By dragging the whole bar we move the track to a different time point. This modification and further editing of a track can be done also by right-clicking on the track itself. This brings up the corresponding context menu illustrated in the picture below. The last option un-trim track is available only for previously trimmed animation tracks, its function is to extend the track back to its original length and it will be closely described further in the text.

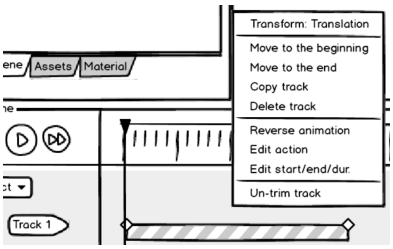


Figure 6.7.4: Low-fidelity prototype - animation track context menu

The other options are mostly self-explanatory, but the edit action and start/end/duration features need additional user input of their properties. This is done in the Animator component similarly as the preset animation is set up to maintain a consistency of the UI.

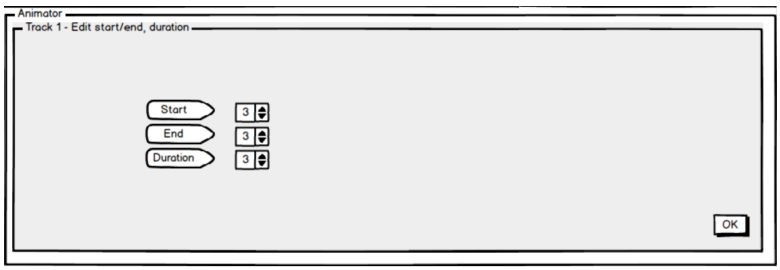


Figure 6.7.5: Low-fidelity prototype - track time editing

The keyframes at the Animator can be edited too. Moving the keyframe in time is possible by simply dragging the keyframe. The keyframes are hierarchically organized, by dragging the top keyframe (e.g. the position/translation) we move with all the axis keyframes, by dragging the axis keyframe separately we change just the corresponding axis keyframe. More possibilities are provided by the keyframe context menu that is brought up by right-clicking a keyframe (refers to the Keyframe context menu problem).

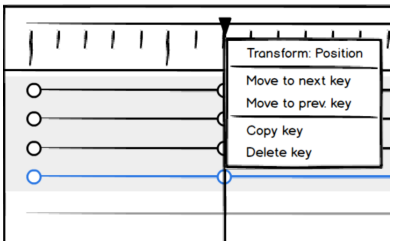


Figure 6.7.6: Low-fidelity prototype - keyframe context menu

6.8 Other Controls and Features

The mouse controls for model view customization and object transformation stayed unchanged but will be one of our main concerns in the subsequent part. Briefly, when we focus on mouse controls, the right button is restricted for action, this way we can click on all the tools, select the object, or move the object. The left button is used for custom view change, pressing the button and moving around with the mouse we change the model view. For zooming out or in the model view the scrolling is used.

Any keyboard controls were not determined at this stage of the low fidelity prototype yet and their configuration (Keyboard shortcuts layout problem) is devoted to a portion of the following part.

The Timeline time scale shows a time window on the whole timeline. By scrolling on the time scale we zoom in or out and the time scale changes. The same applies to the Animator time scale except here we have just one animation track's time scale available. Another important feature is to provide snapping (Fine-tuning problem) of individual tracks when extending/shortening or moving them in time. Endpoints of the tracks should snap next to each other on-demand to simplify alignment. Also, movement in discrete steps would be provided on-demand by using a meta-key. The same fine-tuning techniques apply to the 3D scene and model/object manipulation.

When an animation track is extended or shortened there are two options for the resulting track. These features build upon the End wrap feature options of the existing Misterine Studio's design (Problem 9). Scaling is the default approach when all the keyframes are rescaled to the new length of the track. The second approach is trimming when all the keyframes are fixed at their current position and the animation track's time is just extended or in case of shortening the outlying keyframes are cropped out. The important feature for final usability is to be able to see the cropped-out portion of the track. The concept is illustrated below. This trimming option could be for example introduced by pressing a meta-key while dragging the track's endpoint and therefore we would eliminate the hidden-feature problem from the existing design.

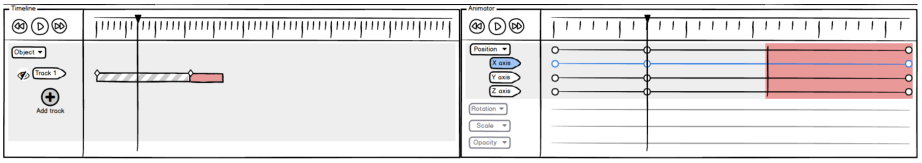


Figure 6.8.1: Low-fidelity prototype - trimming in

Chapter 7

Usability Testing and Prototype Conclusion

In this chapter, we examine the proposed low-fidelity prototype of the new UI design created in the previous chapter and evaluate the most essential concepts for desired use cases. In the end, we derive a conclusion that will establish a base for the high-fidelity prototyping part.

7.1 Low-Fidelity Prototype Usability Testing

The prototype itself was already closely depicted in the previous chapter, therefore there is no need to go through this process again and we will step into the usability testing directly. The essential goal of the testing is to evaluate the proposed design of the 3D Scene workspace, particularly an animation track addition or creation and the track's keyframe editing.

Both tests were carried out remotely due to the COVID-19 situation at this point, nevertheless, we tried to minimize this distance barrier. Since the prototype does not have any interaction implemented in this phase yet and consists of several steps or states of the application captured in sketches, the process of testing was performed as follows. Each participant was contacted via Skype[1] communication tool and briefly introduced to the problematics of the AR, 3D modeling, and goal of the research. Moreover, there was no additional instruction for the participants on how to use the prototype since they were familiar with similar kinds of software to fit our personas and use cases mentioned in the first part of the thesis. Each participant was given the same rather small set of subsequent tasks to complete while his satisfaction, confusion, reactions, etc. were captured. The prototype was provided throughout a screen sharing. In the beginning, the participants were provided with a short time for a quick overview of the main prototype screen and were asked to think aloud during the whole process of testing. During the process of testing the user verbally expressed what he is doing, clicking, etc. so the showing screen could have been changed accordingly by the moderator and so the interaction was induced. In the end, the participant provided us a quick summary of his experiences, and the test was finished with a friendly discussion. Each test took around 45 minutes with all the

[1] https://www.skype.com/en/

necessary introductions and conclusions.

7.1.1 Usability Test 1

The first usability test participant is a 25-year-old design and engineering, postgraduate student. He has a background in electronics, multimedia technology, and video editing. From the point of view of our use cases, we could describe him as a Graphic designer. He is more focused on aesthetics throughout his work while video editing is one of his major hobbies but still, he has some minor knowledge about the technologies and principles behind the scene. The key terms such as animation and 3D modeling principles are well known to him that are crucial in this part since the low-fidelity prototype focuses only on the 3D object animation part of our application.

Simple View and Object Manipulation

In this task, the user was asked to change the viewpoint of the 3D object and rotate it around the Y-axis.

1. The participant went straight for the mouse controller to move the viewpoint, but he was a bit hesitant when choosing the mouse button to pan the view which he intended to do. This inconvenience will be later solved by the precise definition of controls. So the participant was encouraged to continue and use the buttons he is familiar with from other software use. By choosing the scroll mouse button he panned the view and continued with a lookup of the tools to rotate the 3D object. This control corresponds to the present Misterine Studio's UI design.

2. He quickly located the Toolbar and the selection tool to first select the object and clicked the object to select it. He was excited by the highlighting of the selected object also in the object explorer. At this point, the user started to mention some keyboard shortcuts (such as pressing E on the keyboard to enable rotation tool) but these are not determined yet so he was asked to use just the visible tools in the UI. The rotation was then performed flawlessly using the circular controls.

3. In the end, the participant reached the goal of this task. The key outcome from our brief summary would be the keyboard shortcuts implementation that he is used to using for effective workflow.

Object Animation Addition and Creation

The task can be split into two subtasks, the custom animation, and the preset animation addition and creation. The first job was to use a preset animation and add it to an object. The second job was to basically repeat the process but to add another animation to the same object with the use of a more advanced option of the custom animation. In the second subtask, the user was asked to create an animation of translation.

1. Contrary to the preceding task the participant was a bit stuck at the beginning of this task. It took him a while to discover the button to add animation track in the Timeline. But once he found the button, he picked one of the preset animation options from the context menu and intuitively reoriented his focus on the Animator where the preset animation parameters input fields occurred.

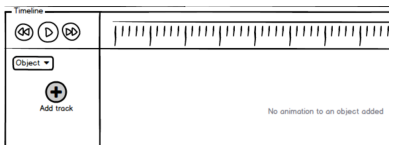


Figure 7.1.1: Low-fidelity prototype testing - Add track button

2. When setting the animation preset parameters he did not understand the input fields well. He had some ideas but it was not clear what is meant by the Target axis parameter and the Transition type select icons. Therefore a brief explanation followed after which he set the animation parameters and completed the first part of the task.

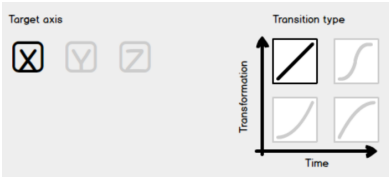


Figure 7.1.2: Low-fidelity prototype testing - preset animation parameters

3. At this point, the participant was to ask to add another but custom animation to the object. His action was again clicking the add animation track button in the Timeline, and choosing the custom animation option. This enabled the keyframe editing in the Animator and which caused the user to look for a keying tool that he could use to capture the keyframes. His first attempt led to the Animator, later on, he searched the Toolbar, and at last, he found the control in the Animation explorer. At this time he also discovered the alternative way to add an animation track to the Timeline directly from the Animation explorer.

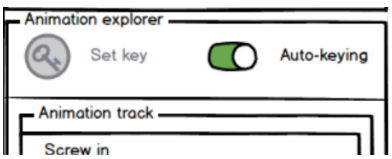


Figure 7.1.3: Low-fidelity prototype testing - keying tools located in the Animation explorer

4. The rest of the animation process was straightforward and flawless. He was used to working with similarly designed video editing software and

used the auto-keying option to create the animation. The only downside he mentioned was that he is not able to see the precise duration and end times of the animation tracks, but we will depict this issue in more detail in the next task.

Animation Track and Keyframe Editing

This task is based on the previously made animations. The participant was asked to perform time changes to an animation track and to reverse an animation. Then he was asked to change the position of several keyframes in the time as well as the keyframe transformation parameters. As an addition, the animation track trimming design was examined at the end.

1. The first thing the user did was simply drag the animation track bar in the Timeline to a different timepoint. At this point, we again encountered the problem with no precise timing of the track visible right away. For further track editing, the participant first looked around the whole UI, which caused a slight disengagement from the main goal, and he got stuck. Following a hint from the moderator, he used a right-click on the animation track to bring up the context menu where he could pick the operation needed, while he also discovered the option to precisely set the time properties of the track using the context menu. The context menu can be seen in figure 6.7.4.

2. After reversing the animation track he moved to the second part of the task which was keyframe editing. Since the user was familiar with keyframing as mentioned before the process was fluent and satisfactory. When editing the object properties for specific keyframes the participant properly clicked the intended keys and changes the transformation values in the Property editor.

3. In the end, we explained the concept of the animation track trimming option to the user and asked him to perform it. His first impression was a bit overwhelming, he did not expect such significant visualization of the track trimming, but he got the essential idea that there is a part of the animation track that is still valid as well as the trimmed out part that is not executed which preserves the left out keyframes.

To summarize this usability test the participant provided feedback where he wanted to highlight mainly the issue with accessibility of the animation track properties. This problem was caused by the simplification of the UI in the low-fidelity prototype. Already the existing Misterine Studio's UI implements such fields to quickly see and edit the track's parameters at the bottom of the Animator component.

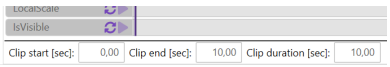


Figure 7.1.4: Low-fidelity prototype testing - track's parameters at the bottom of the Animator component of the existing design

Other issues discussed, mainly the placement of the keying controls that is a bit misleading will be dealt with as part of the high-fidelity prototyping. Overall experience was satisfactory, but as the participant stated, there were some stages where he did not directly know what to do and got stuck for a while. But these shortcomings are to him just a matter of the first experience with the UI design.

To provide a quick learning ability test, the participant was asked to perform one more animation of his selection (in this case rotation was chosen). Which confirmed that once the user got more familiar with the UI the workflow was fluent and effective. The orientation in the prototype was quicker and his reactions more comforting.

7.1.2 Usability Test 2

To cover both presented personas the following test participant is more engineering-oriented. A participant is a 30-year-old man working in an engineering company as a construction designer. He has experience mainly in industrial engineering while using CAD software is a part of his daily work routine. Throughout his work of designing, he has to follow several regulations for the projects he is working on and make sure that every piece fits the purpose and works well. Therefore the participant fits best the Design engineer use case since he understands and knows very well the working principles, individual parts, and use of each product. Nevertheless, his great knowledge of CAD software gives him also some of the capabilities of a Graphic designer. Therefore the work with the 3D scene workspace of our application should also be well-designed for him without any big limitations.

The individual usability test tasks exactly correspond to the ones stated in the usability test above so in this section their description is skipped.

Simple View and Object Manipulation

1. The first reactions of the second participant were almost identical to the first one. He quickly looked around the UI and used the mouse to manipulate the viewpoint. In this case, the user wanted to rotate the view, and based on his experience he pressed the scroll mouse button and moved the mouse in the scene to achieve the view rotation.

2. Moving on to the 3D object manipulation, specifically the rotation, the participant got a bit confused. Even though he quickly located the rotation tool on the Toolbar, and clicked on it, he expected to see some controls to be immediately shown alongside the object to enable the transformation. After some time he realized that he did not select the object. To do so the user clicked the object, which enabled the tool for the selected object and he could perform the task as he expected.

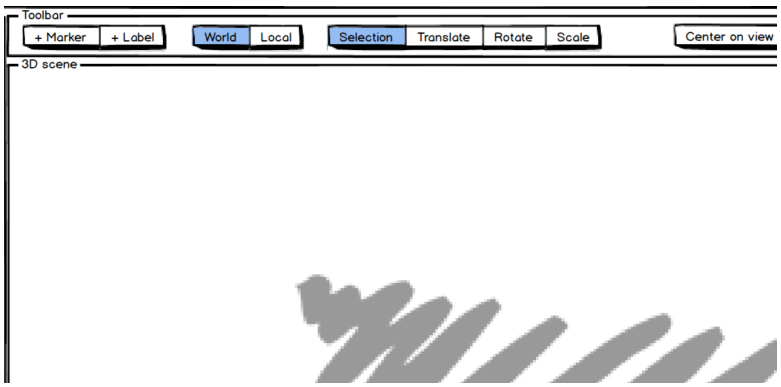


Figure 7.1.5: Low-fidelity prototype testing - even when no object is selected the tools stay enabled

3. To sum up this task the participant stated that he would like feedback from the app when selecting a tool without selecting an object that the tool should be applied for, or to generally approach this issue in a different way. A solution to this problem would be enabling the tools associated with an object only if the object is selected as it is in the already existing design. Therefore this problem is generally caused by the simplified low-fidelity prototype than the UI design itself.

Object Animation Addition and Creation

1. As opposite to the aforementioned test case, the participant rapidly located the Animation explorer which at this time was disabled since he did not select the 3D object to apply the animation on. Following the hint to select an object in the Animation explorer he enabled its capabilities and clicked one of the preset animation options. At this point, the user hesitated a while until he saw the animation track in the Timeline and its settings in the Animator on the bottom of the screen. This was probably caused by a slight lag between the participant's reaction and the moderator changing the visible screen.

2. Setting animation preset parameters followed the same pattern as in the previous test case. The user correctly guessed the function of certain input fields but it was not instantly clear what they mean and what the final result will be. This issue was already illustrated by figure 7.1.2 during the first usability test. Meanwhile, he stated that it would be nice to have a closer description of the animation preset than just the label itself to really understand what animation he is about to use.

3. Starting with another animation addition, in this case, the custom animation, the participant now used the add animation track button in the timeline (not the Animation explorer options). This was followed by correctly choosing the custom animation from the context menu which

brought up another animation track in the timeline as the participant expected.

4. The custom animation creation was a bit tricky for the participant and not fluent. First, he tried to manipulate the object (while auto-keying enabled by default) which was immediately setting a keyframe in the Animator. This was not behavior he would expect, when he basically starter to verbally describe workflow corresponding to manual keying option (auto-keying disabled). Since he got stuck at this point and could not locate the keying option while looking mainly in the Animator component, he was proposed a hint to look in the Animation explorer (shown in figure 7.1.3). From this point the process was smooth, the participant disabled the auto-keying option and used the manual set key button to create the animation. Also, the manipulation with the object improved after the first task attempt.

Animation Track and Keyframe Editing

1. Using the previously created animation tracks the participant dragged the end of one of them to extend the track in time. As he expected the keyframes got rescaled to the new time range but equivalently to the first test case he mentioned that he would like to see the time range of the animation track precisely somewhere in the UI. For the next subtask, the participant first suggested using a control somewhere in the Animator to reverse the animation but since there are none of these controls he proposed to right-click on the track (corresponding to the prototype's design) which brought up the context menu where he picked the reverse option and accomplished the goal. Moreover, he tried to set precise time endpoints for the animation track using the context menu option, which changed the content of the Animator component to the track time properties input fields. The precise track editing options using the Animator component is illustrated in figure 6.7.5. This caused confusion for the user since it took a while for him to find the confirmation button in the bottom-right corner to get back to the Animator keyframe view.

2. Keyframe editing and the transformation changes to a specific keyframe went flawlessly without any problems or inconveniences. Contrary to the first test participant, this time the user did not use the Property editor to change the object properties but he directly manipulated the object.

3. The same as in the first test case was true in this case. The participant got the basic idea behind the animation track trimming right and was satisfied and understood its implementation. Moreover, a possible improvement that he mentioned would be a feature to get rid of any trimmed animation track parts (mainly keyframes and visual representation) when the user is sure he is done with the work.

In conclusion to this usability test, the participant stated that after the first

task and getting to know the UI prototype he was getting more confident and comfortable using it. To support this opinion we concluded a second simple walkthrough through the animation process as well as in the first test case. The results were quite impressive and analogous to the first case. The orientation in the UI and overall experience was getting better. Despite the fact, the participant mentioned the inaccessibility or hidden accessibility of the animation track properties as a key issue. As already mentioned in the previous usability test the issue of inaccessible track properties is more of a low-fidelity prototype issue than a design issue.

7.2 Low-Fidelity Prototype Outcomes

The low-fidelity prototype usability testing has shown that the overall concept of the UI is correct but has still some shortcomings in a term of good user experience and accessibility of some of the components and controls.

To conclude the outcomes, the major issue we should address in the following design is that the animation track properties such as time endpoints or duration should be directly accessible and visible whenever a track is selected.

Remark 1 (Track properties). Following the existing design of the track property information/input fields at the bottom of Animator (shown in figure 7.1.4) has shown to be good practice and essential for users.

Another important feature or component that should be improved is the Animation explorer, mainly the keying controls would be better to reposition into the Animator component as the usability test has shown. It also makes better sense to place these controls next to the items or features that they are used with.

Remark 2 (Keying controls). Keying controls should be placed directly next to where the keyframes are visualized and manipulated.

Unfortunately, the tests did not show the use of the viewpoint presets proposed by the interactive 3D cube designed (introduced in the section 3D scene of the previous chapter and illustrated by figure 6.4.1) and placed in the UI. This fact was probably caused due to a lack of knowledge about the functions of the interface and mainly the interactivity of the cube. Nevertheless, as the previous analysis has shown having an option of preset viewpoints of the 3D model is crucial for a good user experience.

Another valuable concern mentioned by one of the usability test participants is that it would be nice to have a feature that would enable the user to save the current state of his work. Even though the application automatically saves every work step, the advantage of this feature would be that the user could save the current state of his work, name the state accordingly, and continue working. Later on, if the user decides to revert back to the state he would just easily pick the saved one without exhaustively searching the work history.

Remark 3 (Snapshot saving). Saving a snapshot of a partial work would be a nice-to-have feature to enable the user to save and store the actual state of his work for occasional use.

Other improvements and application control definitions such as the naming of some controls, addition of a detailed description of preset animation, or the keyboard shortcuts will be also addressed in the following part of the thesis and tested via implemented high-fidelity prototype.

Part III

High-Fidelity Prototyping

Chapter 8

Requirements, Features, and Specification

In this chapter, we closely describe features, their function, and how we design them. Minimum requirements for the Misterine Studio use are defined as well. We also provide conditions for their successful implementation and user interaction.

8.1 Minimum Requirements

As mentioned in the 4th chapter it is good practice to implement fully mouse accessibility along with keyboard accessibility to satisfy both user categories. Despite this fact, the proposed design requires a user to own and use both keyboard and mouse control devices. The justification for this minimum requirement is that using the mouse is significantly more efficient for manipulation of the objects in the Process scheme workspace, furthermore, this applies even more in the 3D scene workspace. On the other hand, the keyboard shortcuts for effective workflow and meta-keys extending the functionality of mouse controls are crucial to provide a user such a complex tool. Even though we strive to maximize keyboard accessibility. The use of a powerful workstation, a computer with a multiple-core processor, dedicated graphics card, and enough computational memory coupled with at least a 22-inch and Full HD (1920x1080 pixels) resolution screen is the minimum recommended configuration for the use of a complex 3D modeler such as the Misterine Studio.

8.2 Workspace Division and Component Layout

Based on the outcomes of the previous chapters and mainly the low-fidelity prototyping we slightly modified the layout of the Misterine Studio's workspaces. As was already suggested (refers to Window management problem) the whole application now uses only one window which hosts both the Process scheme workspace and the 3D scene workspace. Its implementation will be precisely depicted in the subsequent chapter. To create a foundation for the following sections of features, requirements, and primarily the accessibility and controls the pictures below show the proposed layout of each workspace and its components (denoted by capital letters).

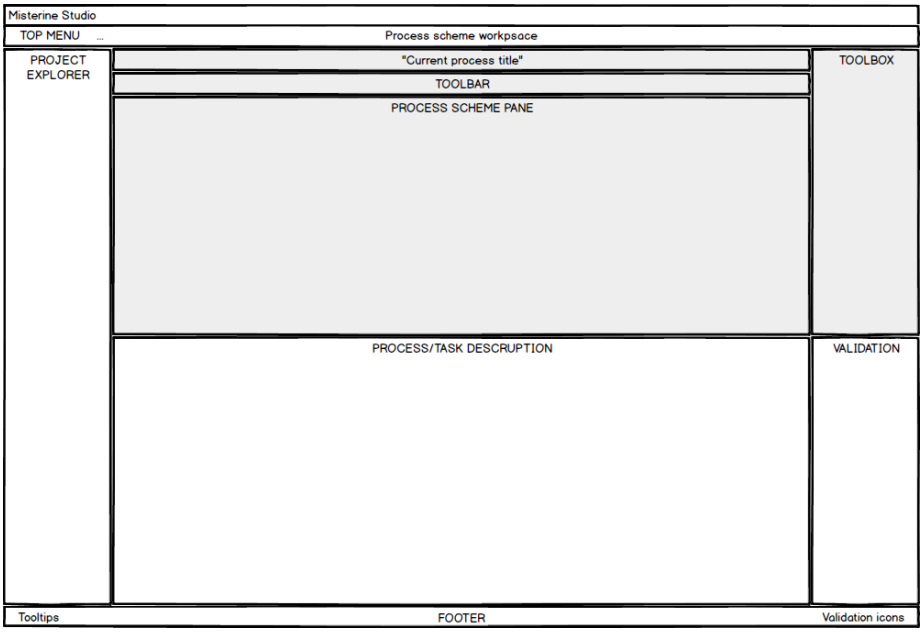


Figure 8.2.1: Process scheme workspace basic component layout

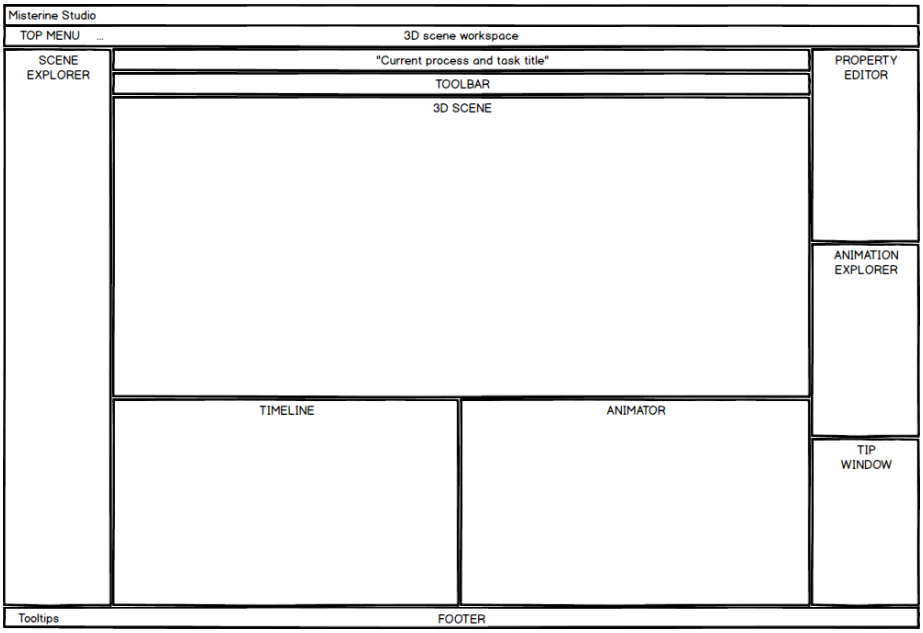


Figure 8.2.2: 3D scene workspace basic component layout

8.3 Component Features and Their Specification

In this section, the newly proposed component features and their specification of each workspace or their changes from the existing Misterine Studio's design will be listed and their function closely depicted. We will also state precise implementation conditions for each of them. Later on, we will pick the

most essential ones (3D scene workspace related ones) for our use cases, work effectiveness, or user experience, and evaluate the proposed solution throughout the high-fidelity prototype.

- The response time for each action should be lower than 1 second. Most of the controls such as tools in the Toolbar, animation track addition in the Timeline, keyframe, or track parameter modification should perform instantaneously within this time limit. For such tasks, no additional visual feedback is needed but we should strive to minimize the response time as much as possible [18].

- If the action is computationally more intensive, such as 3D model import or the preset animation regeneration and thus the system response time is longer than 1 second the user should be always visually informed about such state (figure 8.3.1).

- Cursor hinting is essential to let the user know about possible actions. It should be implemented on active controls in the 3D scene as well as in the Timeline (for animation track pan, or extension, etc.) and Animator component (for keyframe pan, or timescale zoom, etc.) where this hinting gives the user feedback on the interactive elements (figure 8.3.2). This practice was already mentioned in the Usability principles chapter.

- Some of the changes are only adding a new tool to the existing toolset. Therefore if not mentioned otherwise the implementation conditions stick to the existing design pattern of the Misterine Studio.

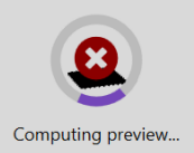


Figure 8.3.1: Example of already implemented visual feedback of proceeding task (for tasks taking longer than 1 sec.)

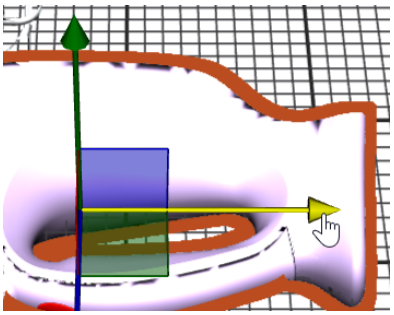


Figure 8.3.2: Example of already implemented cursor hinting in the 3D scene

8.3.1 Process Scheme Workspace

Even though we analyzed the Process Scheme workspace it is not our main target in this thesis. Nevertheless, its design has some flaws which we analyzed and propose as changes to the existing design. If not specifically mentioned the implementation of these changes should stick to the existing component design patterns.

Top Menu

The Top Menu and its submenus stay generally unchanged. The only addition here is that the Project submenu should contain a feature such as “Save current state”, or “Save snapshot” (refers to Remark 3 based on the usability testing of the low-fidelity prototype). Although the application uses an auto-saving method so the user does not have to worry about losing his work it is useful to provide the user with a snapshot of the work state in a certain time to enable the user to quickly step back to a state that he can define. Clicking on the “Save snapshot” should open a save dialog analogous to the “Save Project As” option (figure 8.3.3) and the dialog should be modal as well.

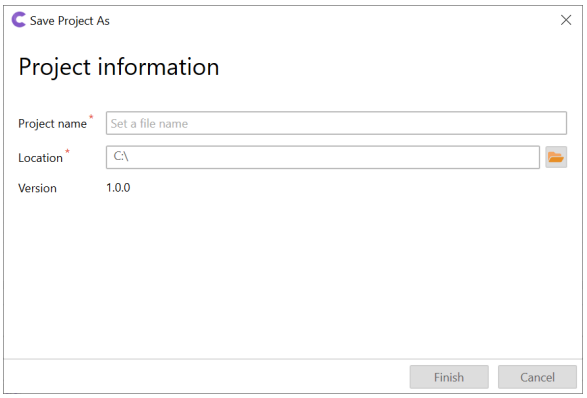


Figure 8.3.3: Top Menu - Save Project As dialog window

Project Explorer

Project items are hierarchically organized in the Project Explorer. In one Misterine Studio instance, only one project at a time can be opened or displayed. This results in a Project as a top-level item while the Processes folder and Resources folder are its children. Using right-click context menus the processes, respectively the resources can be created or imported. Functions such as rename option, copy, paste, delete are indeed available for the processes as well as the resources. The only crucial improvement to the existing design is an indication of the selected or viewed process. This should be done in a similar way such as indication a private resource that is unsharable. Using a simple icon indication of the process will improve the user’s experience and orientation (Problem 2). The proposed icon symbol is the View symbol from

the Segoe MDL2 Assets[1] symbols or some of its alternatives.

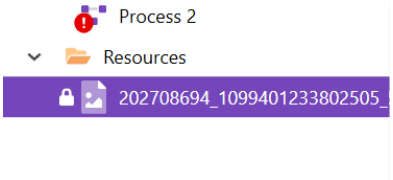


Figure 8.3.4: Project Explorer - Unshareable item indication (lock symbol)

Process Indication Label

The aforementioned viewed process indication should be also implemented for the Process scheme pane and located above its Toolbar as illustrated in the workspace layout picture to moreover overcome the State indication problem. This label should consist of the name of the process only.

Toolbar

Moving on to the Toolbar the only changes necessary are newly proposed features. First is the "Show grid" toggle to enable, or disable the grid shown on the pane available always when a process is viewed. The toggle should always indicate if the grid is enabled or disabled the same way as the transformation tool toggle selection (Select, Translate, Rotate, etc.) in the 3D Scene workspace is implemented. A symbol used for the "Show grid" toggle should be equivalent to the TiltDown symbol from the Segoe MDL2 Assets. The next new function called "Center on selection" should provide zooming the selected objects to the window of the process scheme pane. The "Center on selection" option should be available only if an item of the process scheme is selected. If only one scheme item is selected the window should zoom the item to fit the whole window, if multiple items are selected then we fit all the selected items into the window. This feature is analogous to the already implemented one in the 3D Scene workspace, and therefore the same symbol should be used. These controls should be added to the Toolbar alongside the Reset layout, Duplicate, and Delete options.

Process Scheme Pane

In the Process scheme pane, we can create a process scheme while each task of the process can have its description, title, etc. Focusing on the title which can be changed only through the Task description component by the existing application design is a little inconvenient. The possibility to change the Task's title directly by double-clicking on the Task's title in the process scheme would be largely more efficient and intuitive. When double-clicking on the title label should change to the input text field where a user can rewrite the

[1] https://docs.microsoft.com/en-us/windows/apps/design/style/segoe-ui-symbol-font

title, by clicking away or pressing enter the title change would be confirmed and the title changed back to the label state.

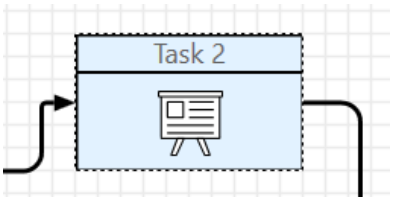


Figure 8.3.5: Process scheme pane - Task title change

Footer

The existing Misterine Studio design uses footer space to show the exact project location in the computer file system on the left side and validation information on the right side. Since we can access the project's location using the right-click context menu on the Project explorer component, there is no crucial need to explicitly show the project's location all the time. Eliminating this would enable us to use the space of the footer for a tooltip providing additional information for the user. This tooltip should be implemented for every tool and feature of the application and should state the name of the currently selected tool and brief action suggestions. Alternatively, when a meta-key is pressed it should provide possible action suggestions as well (inspired by Blender's tooltips and resolving the Problem 7). The footer tooltip will be described in more detail in the following section of the 3D Scene workspace where the implementation of this feature is equivalent.

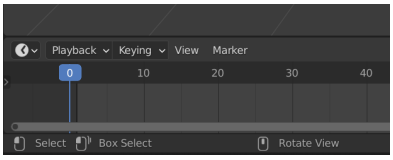


Figure 8.3.6: Blender meta-key tooltip

We left out some of the components that you could see in scheme 8.2.1. The existing design of these components follows the usability principles and no problems were revealed during the design analysis except the accessibility that will be resolved in the next chapter together with user interaction controls.

8.3.2 3D Scene Workspace

As in the previous part, the implementation specification follows the design of the existing solution if not mentioned otherwise. The major change to the design to improve the window management minimization criterion is that the 3D Scene workspace content replaces the Process Scheme workspace content when a 3D Scene is opened so no additional window opening is needed anymore. Another significant change is that the History component

got removed on behalf of the same principle of the undo or redo history as is implemented in the Process scheme workspace to maintain the UI consistency.

Top Menu

The newly introduced component of the 3D scene workspace is the Top Menu which design is generally derived from the Process scheme workspace's Top Menu. This component should provide a clickable field "Back to process" to allow the user to go back to the Process scheme workspace, and the option "Save snapshot" to save the current state for the same purpose mentioned in the first point of the previous Process scheme workspace section. The option "Import from CAD" to import CAD files should be also located in the Top Menu and not in the Toolbar as it is in the existing design. All of these clickable fields should be implemented the same way as the top-level fields in the Top Menu of the Process scheme workspace in the existing solution (figure 8.3.7) and should be always visible.

- "Back to process" feature corresponds to the window management minimization introduced in the new design. Therefore a button to go back to the Process scheme workspace is needed. Clicking on "Back to process" should take the user back to the Process scheme workspace by replacing the content of the window. While the corresponding task which 3D scene was previously opened (respectively also its process) is selected.
- "Save snapshot" feature should follow the same principle of opening a modal save dialog described in the Process scheme workspace specification section (Top Menu subsection).
- "Import from CAD" feature implementation is based just on relocation of the already implemented one in the Toolbar of the existing solution.

Figure 8.3.7: Top Menu design of the existing Process scheme workspace

Scene Explorer

The Scene explorer component visualizes the whole hierarchy of 3D model parts, as well as other resources separated by its tabs between which the user can switch. By using the search box on the top the user can filter out the items of interest. It also provides filtering based on the type of the object or its properties using simple shortcuts which the user needs to know (refers to Problem 5). To overcome this fact and further improve the filtering the proposed design should provide predefined filters in a form of small icons below the search box that can be toggled such as "Show 3D model objects" or "Show animated objects", etc. Another additional feature of the new design is adding a pictogram indication to items that are animated, this should be

done the same way as the indication of the currently viewed process in the Process Explorer of the Process Scheme workspace. This directly resolves the problem of Labeling and tooltips mentioned in the UI analysis. Other features and their layout remain the same as in the existing design of the Misterine Studio.

- The implementation of predefined filters should be similar to visible layer selection toggles already implemented in the Toolbar (figure 8.3.8). When the corresponding filter toggle is checked then the corresponding items should be visible in the explorer. The proposed filters are "Show 3D model objects" (using the same symbol as 3D model objects are labeled within the existing design), "Show animated objects" (using symbol VideoSolid from the Segoe MDL2 Assets or similar), "Show tracking marker" (using existing tracking marker symbol) and "Show labels" (using existing label symbol), these filter options should be always visible together with the search box and placed below the search box at the top of the Scene Explorer.
- The indication of an animated model item should follow the implementation of explorer item labeling (figure 8.3.4) already seen in the previous section of the Process scheme workspace design. Using a camera-like icon (the symbol VideoSolid from the Segoe MDL2 Assets or similar) to maintain consistency with previously defined filter toggles.

Figure 8.3.8: Toolbar - Visible layer selection toggles design

Process/Task Indication Label

To clearly indicate to what process and task we are creating the 3D scene (refers to Problem 2) the label below the Top Menu is introduced in the proposed design (figure 8.2.2). This gives the user essential feedback on what he is doing in the form of the structured string label "Process/Task". This label should be always visible and fixed at its position to always remind the user on which task scene he is currently working on. The height and thus also font size of this label section should be the same as the Top Menu height.

Toolbar

Before moving onto the 3D scene itself we have the Toolbar component above it where the user can access all the necessary tools for object transformation and animation creation. As was already mentioned the first "Import from CAD" option from the existing toolbar should be displaced. The other controls and tools are well established and implemented. Except for one missing but a useful feature which is the 4-view layout toggle that provides the user with a switch between the overview of the 4-view layout and the focused

view of the perspective view (resolving the problem of 4-pane viewpoints). This option should be located left next to the "Center on selection" tool in the newly designed toolbar (figure 8.3.9).

- When the 4-view layout is visible the toggle should provide a tooltip "Switch to perspective view" and its icon should be MiniExpand2Mirrored symbol from the Segoe MDL2 Assets or similar.
- When the perspective view is active the toggle should provide a tooltip "Switch to 4-view layout" and its icon should be ViewAll symbol from the Segoe MDL2 Assets or similar, the other implementation details should be the same as the existing tools.

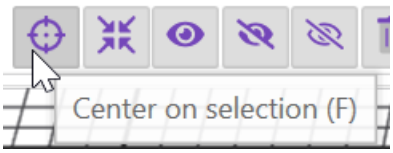


Figure 8.3.9: Toolbar - View tools design

Furthermore, one additional change that should be implemented is the redesign of the Undo and Redo options. These should have the same functionality as in the Process scheme workspace and thus provide a dropdown-like button to contain the command history (see the picture below).

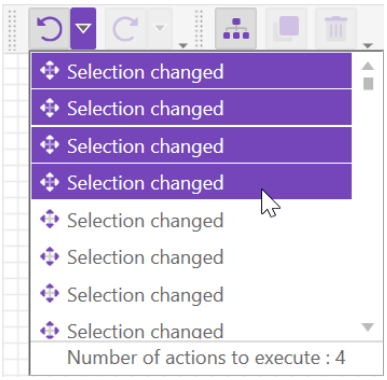


Figure 8.3.10: Toolbar - Process scheme workspace Undo/Redo history design

3D Scene

The 3D scene component is a quite complex one where the 3D objects are visualized and manipulated. The overall design remained unchanged except for providing the 4-view layout option instead of just providing a single perspective view. And also the preset view cube was added to simplify the orientation on the 3D space by providing several preset viewpoints. These two features are not analyzed in the part of prototyping since they are already successfully used for the same purposes in the SOA software (analyzed in part 1 of this thesis).

Property Editor

The Property Editor is the component where the user can set visibility of the object in the final scene, precise transformation state, etc. (see the existing design in figure 5.2.10). To satisfy the need for transformation using another object's axes the toggle button could be used to switch between local axes or another object's axes for each transformation separately (figure 8.3.11). The Tip window component should provide an overall description of the process of using another object's axes for a transformation depicted in more detail in the following paragraphs. Other than that the overall design of the Property Editor remained unchanged however the transformation fields, as well as the object title, the layer toggles, and the visibility toggle on top, should not be collapsible. The additional content of the Property editor can be scrollable if the content does not fit the size of the component.

- When the toggle is switched to the other object's axes option all of the components except for the Property Editor, 3D Scene, and Scene Explorer get disabled. This enables the user to choose the object (which axes should be used) from the scene or using the explorer without the distraction from the other components. Moreover, the object on which we do the transformation should be dimmed since it does not make any sense to select the "Local object". At the same time, a label "Select an object to use its axes" should appear below the toggle while the Tooltip should be filled with the same information.
- When the object gets selected its label is shown above the transformation input fields to provide the user with selection feedback and the previously disabled components get to their previous state. Now the desired transformation uses the selected object's axes for the transformation. This feature is only available for 3D model objects thus visible only when a model object is selected.
- Contrary, when the toggle is switched to the local axes the transformation input fields and additional Property editor content stay as-is.

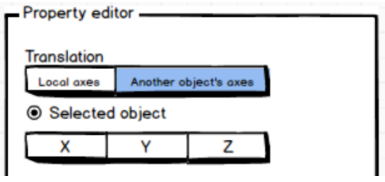


Figure 8.3.11: Property editor - Another object's axes transformation illustration

Animation Explorer

The newly proposed Animation explorer is crucial when creating an animation of an object. This component provides quick access to the preset animation list as well as the custom animation option which the user can choose from

when animating a 3D object while resolving a large part of the Hidden features problem of the existing design. The component follows the design of a simple list of options and its content is available only when a 3D object is selected. This way when the user selects an object to be animated, he chooses one of the Animation explorer options, the corresponding animation track gets added to the Timeline and continues setting the animation parameters in the Animator (respectively further in the Timeline).

- When an option (animation track) from the Animator explorer is selected the animation track is immediately added in the timeline and gets selected.
- The animation track has a predefined duration and the Animator is filled with corresponding input fields in case of a preset animation or with the keyframe view in case of the custom animation.
- The Animation explorer should always show the Custom animation option fixed at the bottom of the list visually separated from the preset animation options. At least 5 of the preset animation options should be always visible and the rest should be accessible by scrolling if necessary.
- The Tip window gets filled with the animation information on the mouse over the animation option to provide the user with the animation description before selecting it. And stays present when the animation option is selected, otherwise gets back to its initial state.

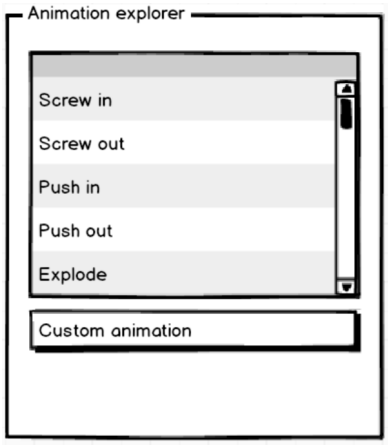


Figure 8.3.12: Animation explorer - Animation list design illustration

Tip Window

Another key addition from the usability and user experience point of view is the Tip Window component. Giving the user, especially a novice user, brief information on what the selected tool or a preset animation will do and how to use it is essential for the successful completion of the intended task. Therefore the Tip window provides a brief textual explanation and manual

for each tool when selected. Furthermore, for preset animations, it should provide a gif-like animated picture to illustrate the selected animation and its parameter explanation. Its implementation refers to Problem 7 and could be inspired for example by the Fusion 360's tooltip visible in figure 5.1.20. Its content should be dynamically changed based on the selected tool or during the animation process and therefore highly depends on the context and state of other components. Consisting of a title referring to the actual tool, selected feature, or situation that occurred, and its brief but a rich explanation so the user has clear information about the following process.

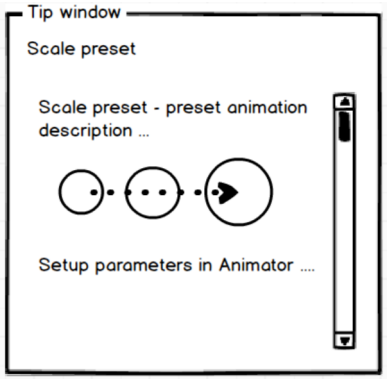


Figure 8.3.13: Tip window - Animation preset tip design illustration

Footer

The aforementioned footer design for the Process scheme workspace should be also applied in the 3D scene workspace by implementing the simple Tooltip into it. Of course, the Validation section of the footer is not relevant to the 3D scene workspace. The tooltips should be dynamic and every time a tool or a feature is selected it should indicate possibilities for the user to act. Therefore every accessible tool or button toggle should have such Tooltip proposing further action implemented. For general tools and pressed meta-keys the design principles shown in figure 8.3.6 should be followed. Providing a pictogram alongside a possible action is very efficient and intuitive. Contrary to the Tip window component the Tooltip does not describe the tool usage but only suggests possible actions when the tool is active.

Timeline

The main concept of the Timeline remained the same. The following points depict the design changes based on the analysis and low-fidelity prototype outcomes.

1. The major change in the Timeline component refers to Problem 8. Each animation track is no longer split into several clips, but it can only have one clip (respectively animation track is one clip). Other than that the tracks can be hierarchized as in the existing design to achieve complex animation creation.

2. When the user wants to add an animation track to the Timeline he can use the Animation explorer component or button "Add animation track" in the Timeline. This button should be placed below the label indicating the object for which the animation is created. If the object's timeline already contains some animation track the button should be placed below the track's label. A plus-like icon should be used for the button while the label "Add animation track" below the button can be placed to further improve the understanding (figure 8.3.14). When the button is clicked a list is raised for the user to select the animation desired. Due to limited space on this list, it should contain just the most frequently used animations (or a feature to be able to predefine the list in workspace preferences would be a nice-to-have). Furthermore, the animation selection should behave the same way as the Animation explorer animation selection.

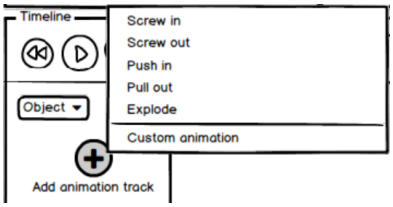


Figure 8.3.14: Timeline - Add animation track button design illustration

3. Important logic needs to be implemented for a case when the tracks are hierarchically laid on top of each other. If tracks are not overlapping there is no problem with their interpretation but in the case of overlapping tracks, we have to examine the animation or more precisely the transformation used. If the transformation type (translation, rotation, scale) is different, the transformations compose together. But we can not satisfy the case when two transformations are of the same type. Therefore the hierarchically higher one gets interpreted and the other ones not, while highlighting this situation is crucial to let the user know about such case. This highlighting should be done using red color to arouse suspicion of conflict in the user. At the same time, the conflicting animation track itself should get a tooltip describing such a situation, as well as the Tip window, which should state the problem when the track is selected.

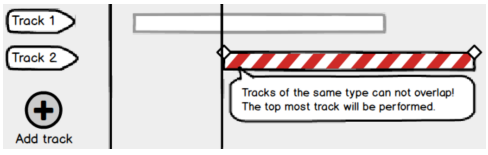


Figure 8.3.15: Timeline - The same transformation type animation overlap indication design illustration

4. To improve orientation between the tracks a feature to be able to name,

label, each track is necessary. By double-clicking the animation track label in the left side panel of the timeline the label should change to a text input which can be used to modify the track's name. Clicking away or using Enter key the modification gets confirmed and the label back to its original state. The behavior should be the same as the proposed task title modification in a scheme of a Process scheme workspace.

5. Also, the possibility to show and hide certain tracks in the timeline would improve usability since the user would be able to reduce its content complexity. Therefore a button with an eye-like icon should be placed alongside the animation track label in the left side panel of the timeline. The button should be implemented the same way as the object visibility toggle in the Property editor (figure 8.3.16). When the track is hidden its animation should not be interpreted when the Timeline is played.

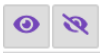


Figure 8.3.16: Timeline - Hide/Show track icon states

6. The track's endpoints should clearly show the ending of the track. Therefore it is better to use a sharp shape of the control to indicate the exact track's endpoints in the timeline. This feature was already implemented in the low-fidelity prototype and can be also seen for example at figure 8.3.15.

7. The concept of track scaling and trimming and their difference was already stated at the low-fidelity prototyping stage (see figure 6.8.1). In addition to the base concept of trimming, the option to revert the trimming to get the certain track to its original state and the option to confirm the trimming to set the trimmed state of the track and remove its cropped out portion. These two options should be added to the right-click context menu (figure 8.3.17) of each track and enabled only if the track was trimmed. Moreover, track extension should be indicated using green color, contrary the cropped-out portion should be indicated with red color. The indication and all the information about trimming gets erased once the trimming is confirmed or reverted.

8. The context menu of each track should consist of the options visible in the picture below. The key addition is the Move to beginning/end option which should move the time cursor to the beginning/end of the corresponding animation track. Moreover, the copy (paste option for the Timeline needs to be added as well) option to improve the workflow was added as well contrary to the existing design.

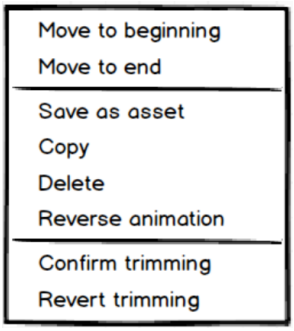


Figure 8.3.17: Timeline - Animation track's context menu design illustration

Animator

The basic idea of the Preset animation view and the Keyframe view (used mainly for the custom animation creation) of the Animator component remained unchanged. Moreover, the so-called F-Curve view is proposed as an even more advanced way to create and edit animations. Although this option will not be implemented in the prototype, it would be a nice-to-have addition to the future developement of the Misterine Studio based on the SOA analysis. Nevertheless, the following points state the major design changes of our main focus.

1. When in the Keyframe view the user needs the option to toggle the Auto-keying on and off. Moreover, a button to set a key should be provided which is enabled when the Auto-keying is turned off. These two controls should be available only in the Keyframe view of the Animator component. Contrary to the low-fidelity prototype where these controls were located in the Animation Explorer component. The "Set key" button should record all keyframes by default but it can also record keyframes for individual transformations on demand. This is enabled by a button with a possible dropdown (following the design of Undo or Redo buttons with history in the Toolbar) while the dropdown should provide the optional keying commands (figure 8.3.18).

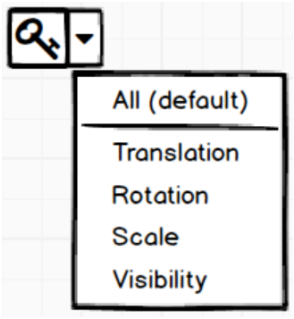


Figure 8.3.18: Animator - Keying options design illustration

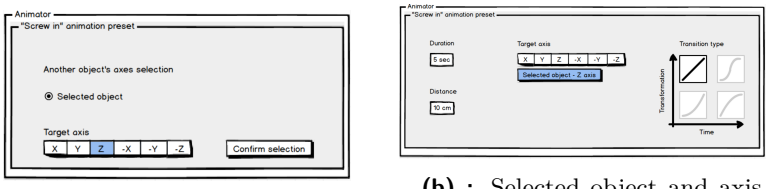
2. Each keyframe right-click context menu should provide an option to move to the previous key in time or to the next one. These two options

should be available only when the movement makes sense (if there is a key to move to). Additionally, the option to copy and paste a key is also introduced and the already implemented option to delete the key remains unchanged. These options always affect the whole set of the corresponding transformation keyframes.

3. The trimming visualization proposed already by the low-fidelity prototype (figure 6.8.1) is crucial for state indication for the user. The portion of the Animator timescale that is extended or cropped by trimming gets accordingly highlighted. If the track gets extended the highlighting should use green color, contrary when the track gets cropped the highlighting should be done with red color. This state indication and all the information about trimming gets erased once the trimming is confirmed or reverted.

4. Moving on to the Preset view which provides input fields to specify the parameters for the animation. The input fields are based on the preset animation and specific to each one. The button "Generate keyframes" was removed from the new design while the animation keyframes are regenerated automatically every time an animation parameter is changed.

5. The major feature added to the preset animation design is the target axis selection which by the new design provides the possibility to choose another object's axis (analogous to the Another object's axes selection of the Property Editor component). In this case, a button is used to start the object and its axis selection process. When the button is pressed the Animator content changes and provides the label "Select an object to use its axes" and disabled target axis toggles (similar to the initial ones) below when no object is selected yet. At this stage the unnecessary components are disabled (Animation explorer, Timeline, Toolbar, Top menu, Property editor) as well as the animated object is dimmed in the scene to reduce the user's distraction. When an object to use its axes is selected the label changes to the selected object title and the target axis toggles are enabled for the user to pick one (figure 8.3.19a). The whole process then needs to be confirmed by clicking the confirm button which brings the user back to the previous Animator content for the preset animation while the "Choose another object's axis" button indicates the selected object and its axis (figure 8.3.19b). The previously disabled components are then set back to their initial state.



(a) : Object and axis selection

(b) : Selected object and axis indication

Figure 8.3.19: Animator - Another object's axes selection design illustration

6. The preset animation furthermore provides an additional toggle at the footer of the Animator to change the view to the keyframe mode for more advanced modifications. This toggle should dynamically change the content of the Animator and should be placed on the right next to the time input fields. The suggested icon for the toggle is the Equalizer symbol from the Segoe MDL2 Assets or similar (replacing the “Advanced” toggle of the existing solution).

Chapter 9

User Interaction and Accessibility

Our goal is to provide understandable controls with a uniform layout to improve efficiency when creating the AR instruction manuals and documentation with our software. The design is divided into 2 respectively 3 main parts, the mouse controls, and the keyboard controls. The introduced controls are based on the most common practices in the previously analyzed SOA 3D-based software. This way we try to minimize the learning curve for people that are already used to such software. While the general controls overlap almost in all the cases, the view/object manipulation or the timeline controls, unfortunately, differ a lot among the software. Therefore we are not able to satisfy every single software user we decided to gather the control model practices of the Autodesk[1] software while striving to create logical and intuitive patterns in the control design. This way we are not strictly following any of the aforementioned software designs but we provide the user with a new control layout design based on common principles. Moreover, the possibility to change any of the meta-keys or keyboard shortcuts to enable a custom control should be also available and is not only essential for a good user experience but also cross-software work effectiveness.

9.1 Mouse Controls

The design of mouse controls is most inspired by the Autodesk software. These controls are then enhanced by nice to have features such as snapping to discrete steps when dragging objects etc. inspired by Blender[2] software.

[1] https://www.autodesk.com/
[2] https://www.blender.org/

9.1.1 General

Button/key combination	Action/Function	Description
Left-MB	Select/Action	Item selection (rectangular selection) or action confirmation
Scroll-MB	Pan	Pans the pane/view
Scroll-MB	Zoom out/in	Zooms out/in the pane/view
Scrolling in/out	Zoom out/in	Zooms out/in the pane/view
CTRL while dragging	Discrete snapping	Snap to discrete steps while dragging items
CTRL + ALT while dragging	Object snapping	Snap to nearby objects while dragging items

Table 9.1: General mouse controls

9.1.2 3D Scene Workspace Specific

Button/key combination	Action/Function	Description
Scroll-MB	Time scale pan	Pans the time scale when pointing to the Timeline or Animator time scale
SHIFT + Scroll-MB	One-axis pan	Pans the view only in a one-axis direction based on the first mouse movement direction
ALT + Scroll-MB	Orbit/rotate	Orbits/rotates the view
Scrolling in/out	Time scale zoom	Zooms out/in the time scale when pointing the Timeline or Animator time scale
ALT + Scrolling in/out	Move in time	Moves in time on the timeline when object with animation selected
Right-MB	4-view/perspective view toggle	Changes from/to 4-view/perspective view mode when pointing to the 3D scene

Table 9.2: Mouse controls specific to 3D scene workspace

9.2 Keyboard Accessibility

As aforementioned, accessibility using mostly the mouse controller is not sufficient to satisfy all types of users. In this section, the keyboard accessibility

for the Misterine Studio will be defined according to best practices used in nowadays applications. Purposed design is based on recommended approaches and well-developed standards of rich web application accessibility design composed by The World Wide Web Consortium (W3C)[3]. Since today's web applications are getting more complex than ever before and people use them several times a day it is convenient to follow its control patterns also for other kinds of application design. [13]

While implementing such accessibility it is crucial to provide a user with clear feedback on what UI element he is focusing on. The fundamental key for keyboard accessibility is the Tab key and is used to navigate throughout the elements of the UI. Together with the Enter, Escape, Spacebar, and Arrow keys it creates the most essential key bundle used. [13][14]

Keyboard focus and selection are the two main states of an element that should be supported visually. Generally speaking, the focus (or sometimes called cursor) replaces the classical mouse cursor and hover highlighting when the mouse is not used. It provides the user information on what UI element he is pointing at and is active at a certain time. Important to mention here is that elements that can receive focus should be always interactive, and it makes no sense to provide focus to non-interactive elements such as logos or labels. When the user decides to select the element or execute its action the state changes to the selection which is identical to mouse selection highlighting. The key behavior of the focus is that it stays visible all the time even with the element selected, and does not change its appearance throughout the application. The well-established focus design is to consistently highlight the border of the element/component in the focus, the selection is then usually visualized by coloring the background of the element. [15]

The proposed design for the Misterine Studio is illustrated below.

(a) : Keyboard focus

(b) : Keyboard selection with preserved focus

Figure 9.2.1: Keyboard accessibility visual feedback design

Succeeding subsections describe each workspace UI component's keyboard accessibility design in detail. For moving focus between the components, the Ctrl key combined with the Tab key is used. To move in backward between the UI components the Shift key needs to be pressed at the same time. This follows the same design as for example here [16]. All the Misterine Studio's components use cyclic navigation, this means that when the last interactive element of the component is reached while navigating, the navigation focus jumps to its first element on the next attempt to continue further in the navigation or vice versa. The navigation between components and their elements is logically ordered from left to right and from top to bottom.

[3] https://www.w3.org/

Key combination	Action/Description
ENTER	Confirm/Select the element, or expand submenu if any exists (expands the submenu and places focus on its first element)
ESC	Step out/Unselect (moves focus to the parent element if any exists)
TAB	Step forward an element (moves focus to the next element)
SHIFT + TAB	Step backward an element (moves focus to the previous element)

Table 9.3: General keyboard accessibility applied in most UI components

9.2.1 Process Scheme Workspace

Following accessibility, rules are divided into a list when each item corresponds to a specific component of the workspace and keyboard controls used to navigate them. The component layout of the Process workspace can be seen in picture 8.2.1.

1. The Menu bar is the first component of the Process scheme workspace. As it is a menu it has some additional options for keyboard accessibility listed below.

Key combination	Action/Description
DOWN	Moves focus to the next element or extends the submenu if available (with the same behavior as the ENTER key function)
LEFT	Moves focus to the previous element
RIGHT	Moves focus to the next element
UP	Moves focus to the previous element

Table 9.4: Menu bar accessibility

2. Project explorer hierarchy accessibility and selection of items is defined by table 9.5. When the focus is moved to this component the focus should be placed on its first element. Just in case an element is selected before the selected element should receive the focus [17]. When the focus is in a certain level of the explorer item hierarchy (e.g. a folder) the iterative steps through the items in the level are wrapped so the when the last item is reached the focus cycles back to the first item and vice versa.

Key combination	Action/Description
DOWN	Moves focus to the next element
LEFT	Collapses the submenu if available and moves the focus to the parent element
RIGHT	Extends the submenu if available and moves the focus to the first submenu element
SHIFT + DOWN/UP	Moves the focus to the next or previous element and toggles its selection
SPACEBAR	Changes the focused element selection state (select/unselect)
UP	Moves focus to the previous element

Table 9.5: Explorer accessibility

3. Moving on to the Process scheme pane, the toolbox along, and its toolbar above it. The toolbar navigation should be coupled with the Process scheme pane by Tab key, respectively the Shift + Tab key combination to move focus into the pane and out of the toolbar and conversely. This rule also applies to the Toolbox and therefore we should refer to these 3 parts of the UI as one component (using Ctrl + Tab key combination once) and each of them acts as one element with respect to the Tab key navigation. If a tool (element) was previously used (focused) it should receive the focus first, otherwise, the first active element should get the focus.

Key combination	Action/Description
LEFT	Moves focus to the previous toolbar element
RIGHT	Moves focus to the next toolbar element

Table 9.6: Toolbar accessibility

The keyboard accessibility for the Process scheme pane works best when the scheme layout is reset since this brings a rectangular layout of the scheme that is easy to navigate through.

Key combination	Action/Description
DOWN	Moves focus to the first (leftmost) scheme element on the line below
LEFT	Moves focus one scheme element to the left
RIGHT	Moves focus one scheme element to the right
UP	Moves focus to the first (leftmost) scheme element on the line above

Table 9.7: Process scheme workspace - Process scheme pane accessibility

Key combination	Action/Description
DOWN	Moves focus to the next tool group below
LEFT	Moves the focus to the previous element
RIGHT	Moves the focus to the next element
UP	Moves focus to the previous tool group above

Table 9.8: Process scheme workspace - Toolbox accessibility

4. For additional process information, we use the Process description or the Task description component depending on the context which provides text inputs and other attachments. General keyboard accessibility controls apply to both, but first, we focus on the Process description component which consists of several tabs that the user needs to be able to access as well as all the items they contain. Using Tab (respectively Shift + Tab) key we can reach the tab list, the active tab always gets the focus.

Key combination	Action/Description
ENTER	Activates the focused tab
LEFT	Moves focus to the previous tab
RIGHT	Moves focus to the next tab
CTRL + PAGE DOWN	Moves the focus and activates the next tab
CTRL + PAGE UP	Moves the focus and activates the previous tab

Table 9.9: Tabs accessibility

Compared to that we can skip this step in the case of the Task description which is not divided into several tabs. But the Task description component hosts a simple text editor that we need to be able to navigate through. The general Tab navigation persists while the text editor toolbar is navigated using the following controls (corresponding to Process scheme toolbar navigation pattern). This means that the Tab key is not used to move focus between each of the toolbars tools but is just used to get the focus into the toolbar, respectively to the most recent tool selected.

Key combination	Action/Description
LEFT	Moves focus to the previous toolbar element
RIGHT	Moves focus to the next toolbar element

Table 9.10: Process scheme workspace - Task description textbox toolbar accessibility

5. The last component is Validation which is used to inform the user about any deficiencies in the scheme. Traditionally using the Tab (or Shift + Tab key combination) we move between the Errors and Warnings toggles and the list below (Tab control is not used to move between validation list elements).

Key combination	Action/Description
DOWN	Moves focus and selects the next element
UP	Moves focus and selects the previous element

Table 9.11: Process scheme workspace - Validation list accessibility

9.2.2 3D Scene Workspace

To create good accessibility of our system as well as the best user experience for potential users the consistency of control layout is the key factor. Therefore the 3D scene workspace's accessibility principles for similar components are almost identical, with respect to their function. The whole 3D scene workspace layout can be seen in the picture 8.2.2.

1. As well as in the Process scheme workspace the first accessible component of the 3D scene workspace is the Top Menu. This component uses the same accessibility principles as the first one defined in table 9.4.

2. The next component is the Scene explorer which again uses most of the principles already specified by table 9.5 when the Project explorer of the Process scheme workspace accessibility was introduced. In addition, Scene explorer uses multiple tabs to split its content into several categories. These tabs can be accessed using already known principles from the Process/Task description component. Using for example the Tab key the user can go through the items in the Scene explorer and finally reach the active tab. Then following the controls listed in table 9.9 the navigation between the tabs is provided.

3. The Toolbar component does not use the Tab (respectively the Shift + Tab key combination) to navigate its elements. The 3D scene workspace's toolbar reflects the navigation defined by table 9.6, coupled with the Enter key for action selection.

4. The aforementioned requirements to use the mouse controller are essential and indispensable mainly for the 3D scene component. The object transformation and manipulation is quite a complex task and to use the software in an effective way the mouse controller is needed. Therefore the design does not provide any keyboard accessibility to this component. Nevertheless, the user is provided with keyboard shortcuts to improve workflow during extensive 3D animation tasks that are depicted in later sections.

5. The Timeline, as well as the Animator component, also belong to the group of components that are designed for use with the mouse controller. But contrary to the 3D scene these components provide basic navigation through its buttons (Play, Start, End, etc.) and input fields (Current time, Start, End, Duration, etc.) using the Tab key or the Shift + Tab key combination to move in the opposite way (see table 9.3). Even so, the specific animation track bars of the Timeline can not be accessed

and modified using only the keyboard. The same principle applies to the keyframes in the Animator when editing a custom animation.

6. The next important component for precise transformation control is the Property editor which navigation follows the general keyboard accessibility controls specified by table 9.3.

7. The Animation explorer component follows the accessibility rules defined in table 9.5

8. To provide additional information about a selected tool, or about selected animation preset, the Infobox component is used. It has no interactive elements and therefore it provides only a scrolling option to access all its potential content using keyboard Up and Down arrows.

9. The History component is a list keeping track of commands or steps during our workflow. Therefore no additional controls are needed and the component follows the general keyboard accessibility controls from table 9.3.

9.2.3 Keyboard Shortcuts and Meta-Keys

To further extend not only the keyboard accessibility but also the workflow effectiveness of the application we propose a keyboard shortcut layout design.

The general keyboard shortcuts are known by almost anyone using any software nowadays available, therefore the design follows the same layout. Moving to the more advanced controls for process creation and scene editing controls, we encounter some major differences in the reviewed software. The new control design is based on logical naming of the tools to make the shortcuts clear and understandable, at the same time we strive to create a structure in the keyboard shortcuts layout so the meta-keys are used for similar purpose operations while still being inspired by the SOA software. As a result, the Alt key combined with another key is used to represent a view change, a Ctrl key coupled with a key is used for an action (scheme/model change). The combination of Ctrl and Alt keys acts as a negation of action or brings alternative/extended options. Single key shortcuts are used to toggle a scheme item for scheme creation or a tool when editing a 3D scene. Further in this section each of the keyboard shortcuts is described in detail with respect to a current workspace or even a specific component.

9.2.4 General

Key combination	Action/Function	Description
CTRL + A	Select all	Selects all items
CTRL + C	Copy	Copies selected items
CTRL + D	Duplicate	Copies and pastes the selected items
CTRL + I	Import	Brings up a dialog box to import file
CTRL + V	Paste	Pastes a cut or copied item
CTRL + X	Cut	Cuts out selected items
CTRL + Y	Redo	Redoes previously undone commands
CTRL + Z	Undo	Undoes the last commands
CTRL + ALT + A	Invert all	Inverts the selection of items
DELETE	Delete	Deletes selected items
ESC	Cancel	Cancels an action/tool

Table 9.12: General keyboard shortcuts

Key combination	Action/Function	Description
CTRL + E	Export	Brings up a dialog box to export file
CTRL + N	New	Brings up a dialog box to create a new project
CTRL + O	Open	Brings up a dialog box to open an existing file
CTRL + P	Print	Brings up the print dialog box

Table 9.13: General keyboard shortcuts specific to the Process scheme workspace

9.2.5 Process Scheme Workspace

These key combinations can be used in the Process scheme workspace when the focus is on the Process scheme pane, the Top toolbar, or on the Toolbox and function as a quick reference to the tools and items needed for scheme creation.

Key combination	Action/Function	Description
C	Connection point	Enables add connection point item
D	Decision point	Enables add decision point item
E	End event	Enables add end event item
P	Sub-process	Enables add sub-process item
Q	Selection	Enables selection tool
S	Start event	Enables add start event item
T	Presentation task	Enables add presentation task item
ALT + G	Grid	Toggles the grid on/off
ALT + R	Reset layout	Resets scheme layout
ALT + Z	Zoom/fit selected	Zooms to fit selected items to window

Table 9.14: Process scheme workspace keyboard shortcuts

When a presentation task of a process scheme is selected we can use the shortcuts for 3D scene operations mentioned in the table below.

Key combination	Action/Function	Description
CTRL + S	Add/open 3D scene	Opens 3D scene when a presentation task with a 3D scene is selected or adds 3D scene to the task
CTRL + ALT + S	Remove 3D scene	Removes 3D scene when a presentation task with a 3D scene is selected

Table 9.15: Process scheme workspace keyboard shortcuts - Task's 3D scene operations

Additionally, each of the presentation tasks in the process scheme could be described and enriched with extra information about tools needed, warnings, etc. To write the description we use an MS Word-like[4] pane with a similar text editing toolbar to such software. Moving the focus to this text field enables text editor meta-keys inspired mostly by the MS Word software [12] and are defined in the following table.

[4]https://www.microsoft.com/en-us/microsoft-365/word

Key combination	Action/Function	Description
CTRL + B	Bold	Toggles bold text style
CTRL + E	Center	Aligns text to the center
CTRL + I	Italic	Toggles italic text style
CTRL + J	Justify	Aligns text to the block
CTRL + L	Align left	Aligns text to the left
CTRL + R	Align right	Aligns text to the right
CTRL + U	Underline	Toggles underlined text style
CTRL + 1	Superscript	Enables superscript text
CTRL + =	Subscript	Enables subscript text

Table 9.16: Process scheme workspace keyboard shortcuts - Task description text editor

9.2.6 3D Scene Workspace

The 3D scene workspace has its own keyboard shortcut layout due to the 3D object manipulation and the animation process tools. The controls are divided into several groups defined by the following tables since the controls are used in a different context of the 3D scene.

Some of the meta-keys can be used no matter if a 3D object is selected or not, nevertheless, at least one 3D object has to be present/imported in the scene.

Key combination	Action/Function	Description
W	Coordinate change	Toggle between the world and local coordinates
ALT + SHIFT + B	Background layer	Toggle the background layer visibility
ALT + SHIFT + C	Context layer	Toggle the context layer visibility
ALT + SHIFT + F	Foreground layer	Toggle the foreground layer visibility
ALT + SHIFT + T	Tracking layer	Toggle the tracking layer visibility

Table 9.17: 3D scene workspace keyboard shortcuts - no object selected

Assuming a 3D object is selected in the 3D scene we can use the controls defined as follows. The object layer property is object type dependent. The tracking marker can be placed only into the tracking layer, the label into the context or the foreground layer, and the 3D model objects into the foreground and background layers.

Key combination	Action/Function	Description
E	Scale	Enables scaling tool
Q	Select	Enables selection tool
R	Rotate	Enables rotation tool
T	Translate	Enables translation tool
ALT + C	Center on selection	Zooms and centers the view on the selected object
ALT + D	Decimate	Brings up a dialog box to decimate selected object
ALT + H	Hide	Hides selected object in the view/scene
ALT + O	Move to origin	Moves a selected object to the origin
ALT + S	Show	Shows selected object in the view/scene
CTRL + L	Add label	Brings up a dialog box to add label
CTRL + M	Add tracking marker	Adds a tracking marker to the scene
CTRL + T	Add track	Brings up a dialog box to add animation track
CTRL + ALT + B	Background layer	Toggle object's background layer property
CTRL + ALT + C	Context layer	Toggle object's context layer property
CTRL + ALT + F	Foreground layer	Toggle object's foreground layer property
CTRL + ALT + T	Tracking layer	Toggle object's tracking layer property
CTRL + ALT + V	Visibility	Toggle object's visibility property

Table 9.18: 3D scene workspace keyboard shortcuts - with 3D model object selected

When an animation track is added to a selected object keyboard shortcuts providing quick orientation in the Timeline are enabled while the focus is in the Timeline.

Key combination	Action/Function	Description
END	Timeline end	Jumps to the end of the Timeline (end of last track)
HOME	Timeline beginning	Jumps to the beginning of the Timeline
PAGE DOWN/UP	Next/previous track	Jumps to the next or previous track beginning
SHIFT	Trim the track	Use trimming option of track extension/shortening (while dragging the end of a track in the Timeline)
SPACEBAR	Playback	Playbacks/pauses the Timeline animations

Table 9.19: 3D scene workspace keyboard shortcuts - Timeline meta-keys

Moreover, when a custom animation track is selected in the Timeline, we can see its time scale and keyframes in the Animator component. Moving the focus strictly to this component changes the behavior of the aforementioned keyboard shortcuts in this way.

Key combination	Action/Function	Description
END	Animator end	Jumps to the end of the Animator (end of the animation track)
HOME	Animator beginning	Jumps to the beginning of the Animator (beginning of the animation track)
PAGE DOWN/UP	Next/previous key	Jumps to the next or previous keyframe
SPACEBAR	Playback	Playbacks/pauses just the animation track viewed in the Animator

Table 9.20: 3D scene workspace keyboard shortcuts - Animator meta-keys

At this point, we can create desired custom animation using the Auto-keying option or precise manual keying. Therefore other meta-keys are introduced while having the custom animation track selected. Additionally, since the user can have the focus in the 3D scene to do the object transformation or in the Timeline to just move in time, etc., there is no specific focus needed for these controls to be accessible.

Key combination	Action/Function	Description
K	Auto-keying	Toggles auto-keying option on/off
CTRK + K	Add keyframe	Adds a key, captures the current state

Table 9.21: 3D scene workspace keyboard shortcuts - Keying meta-keys

Chapter 10

High-Fidelity Prototype

The high-fidelity prototype implementation focuses on the newly proposed features and design changes in the preceding chapters. Therefore the functional details of each feature will not be depicted throughout this chapter. The prototype was created to support mainly these features and necessary surrounding interaction and therefore some tools work just as placeholders to create the overall user sensation without their actual function implemented. Subsequent sections describe prototype implementation details and some essential parts of the application prototype coupled with screenshots.

10.1 Implementation Details

The prototype was developed using Microsoft Visual Studio Community 2019[1] and based on .NET Framework 4.7.2[2] and its Windows Presentation Foundation[3] (WPF) open-source graphical platform to create all the UI elements. Later on, the solution was build and the final executable used during the usability tests was produced.

The solution is divided into several parts containing each component's logic and front-end part. For each component described in previous chapters, a control based on UserControl[4] class was defined from which the whole application was constructed. To illustrate the 3D scene and object transformation the application uses fixed pictures that change dynamically based on the event. The whole prototype's source code is attached to the thesis separately.

10.2 Prototype Summary

Starting with the overview of the prototype which can be seen on the screenshot below you can see the exact image of the prototype and the actual component layout. The prototype's screenshot shows a selected Cube's body with two animation tracks added in the Timeline. As it is obvious from the

[1] https://visualstudio.microsoft.com/vs/community/
[2] https://dotnet.microsoft.com/download/dotnet-framework/net472
[3] https://docs.microsoft.com/visualstudio/designers/getting-started-with-wpf
[4] https://docs.microsoft.com/dotnet/api/system.windows.controls.usercontrol

screenshot the emphasis was on the workflow principles and behavior of the features rather than the complexity of the 3D scene.

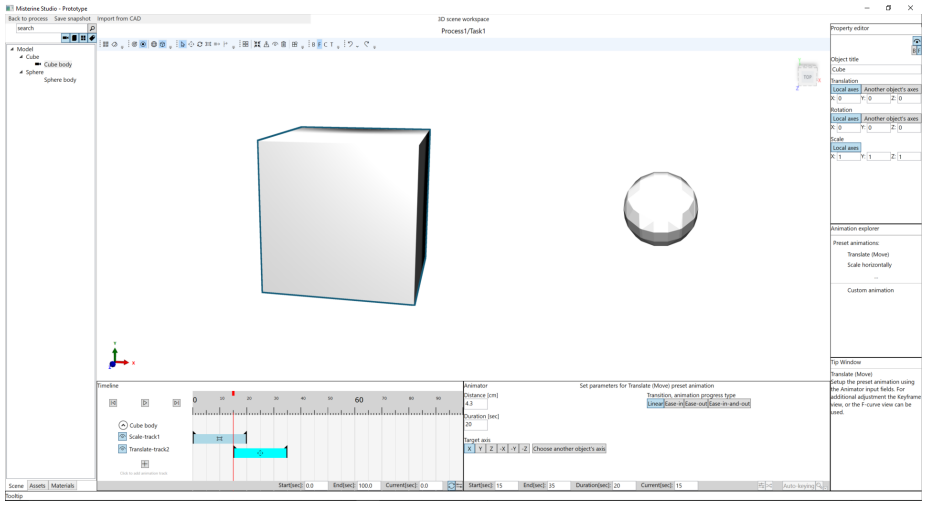


Figure 10.2.1: High-fidelity prototype overview

One of the crucial features implemented and tested later on is the Another object's axes selection feature. This feature and its function was already discussed in the preceding chapters but to show its real implementation the figure below was included.

Figure 10.2.2: High-fidelity prototype - another object's axis selection (for preset animation)

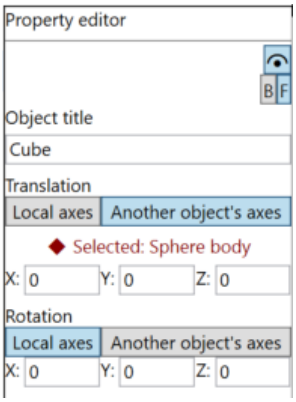


Figure 10.2.3: High-fidelity prototype - another object's axes selection (for general transformation)

Another interesting and essential feature is the animation track trimming this feature can be used to extend the track without disturbing its original keyframes or to crop the track. During the process, it is important to indicate the state to the user. The following figure contains a screenshot of the Animator component as well as part of the Timeline when the track is cropped while showing the cropped-out portion. Moreover, this can be reverted or confirmed in the track's context menu later on.

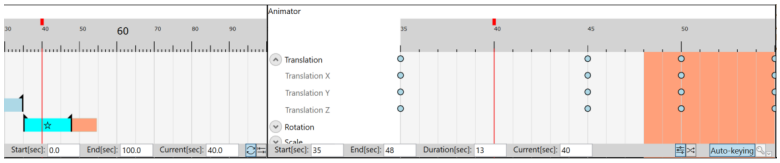


Figure 10.2.4: High-fidelity prototype - animation track trimming indication

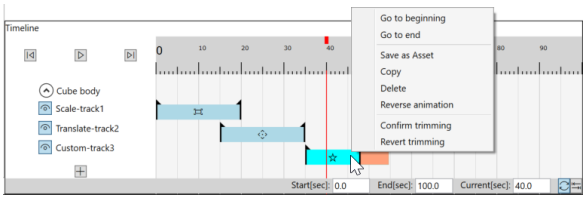


Figure 10.2.5: High-fidelity prototype - Timeline and the animation track's context menu

Chapter 11

High-Fidelity Prototype Usability Testing

The aforementioned high-fidelity prototype was tested to evaluate the proposed design and discover its usability drawbacks to provide a foundation for future development of the application. This chapter consists of a summary of the usability test performed, emphasizing the qualitative usability test outcomes. An in-depth test plan description, as well as each usability test report, is attached separately to the thesis.

11.1 Format of Study

The tests were performed on the application prototype described in the previous chapter. Each test participant was provided a quick introduction to the topic, how the application is intended to be used, and the application's goal. The participants were selected based on the use case scenarios and defined personas at the beginning of this thesis. While striving to include a wide range of participant proficiencies that nowadays use 3D modeling and animation frequently and therefore examine different approaches on the topic.

During the tests, immediate participant's responses and the experience were captured resulting in qualitative research. As additional information, the time spent on each task was measured as well. Based on the [19] the final number of 6 test participants were chosen while conducting one pilot test before to fine-tune each task's process and the interaction with the participant. The testing itself was performed in person with the application prototype running on a desktop setup in an office-like environment. Detailed information on each test, its report, as well as the whole test plan consisting of each test task and overall test setup, can be found as an attachment. Moreover, each test report contains the participant profile, test setup, and each task's description. When developing the test scenarios, the use cases were translated to specific tasks to be easily understandable by the user while avoiding giving suggestions and ambiguity [20].

11.2 Study Goals

The following definitions describe core changes and new features in the application design that are our main goals of the usability study. Test tasks mentioned in the previous section and defined in the test plan that is provided as an attachment are directly based on these goals.

Goal 1 (Animated objects indication)**.** The user should be able to quickly distinguish or filter out the objects that are or are not animated.

Goal 2 (Animation addition, Animation explorer understanding)**.** Animation options should be easily accessible, therefore the user should easily locate the Animation explorer options or the Add animation track button in the Timeline when an object is selected, and thus animate the object

Goal 3 (The same animation type overlap indication)**.** Two animations of the same type can not be satisfied at once, this situation is highlighted in the UI, the user should understand the highlighting of the overlapping animation track and the corresponding tooltip.

Goal 4 (Timeline and Animator animation parameter changes)**.** Small changes such as the time span of the animation should be easy to do. The user should use the track's endpoints to do so (by dragging the endpoints) or the Animator input fields to change the exact time values.

Goal 5 (Custom keyframe animation, keyframing options)**.** Contrary to the preset animations the custom animation at its base uses keyframes. Keyframes can be captured automatically when a transformation is made or manually. The user should be able to set a specific keyframe at a time point he desires.

Goal 6 (Trimming feature and its indication)**.** When the trimming is used the user should be able to distinguish the part of the animation track that is being cropped out or extended. So he is able to see and get back to the original state.

Goal 7 (Another object axes selection)**.** Advanced animations need a transformation based on another object's axes. The user should be able to select the object and its axes when creating an animation.

11.3 Usability Testing Outcomes

During each test, essential information on how the application design suits the user was collected and further analyzed. The overall user impressions about the application prototype design were positive, the component layout of the 3D scene workspace seemed reasonable and as expected to all of the participants. As well as the main keyboard and mouse interaction implemented. Still, some shortcomings or flaws of the proposed design were discovered which we depict in detail in this section. We will start with the most frequently occurring problems among the tests or crucial design flaws and thus the most essential to the user experience and usability of the final design. During these tests also ideas on nice-to-have features were mentioned by the participants which could improve the design as well and will conclude this section.

- The first frequently occurring issue refers to the Goal 1. The core of the problem was that the label indication (camera-like icon) next to the object's label in the Scene explorer is not vibrant enough to be noticed by the user right away. Even though, all of the participants eventually found and recognized the icon with a correct understanding of its meaning. But its location took longer than expected causing user dissatisfaction. This was mainly caused by the size of the camera symbol used for the indication that was quite small and hard to behold and recognize. Therefore as a result a better-sized icon should be used and coloring the icon with some vibrant color to distinguish the animation indication from the surrounding should improve the design as well.

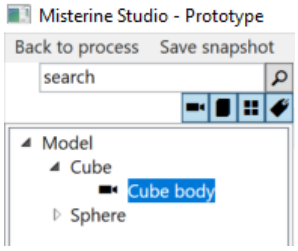
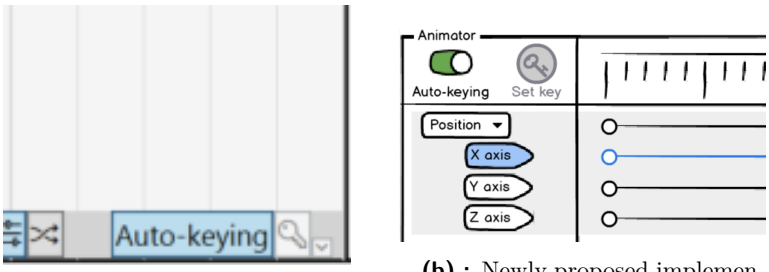


Figure 11.3.1: Animated objects indication

- The next issue that should be resolved is the keying options size and placement since the whole custom animation process relies on their use. The problem occurred frequently when the participants wanted to capture the state of the object at a certain time. Time to look up the keying options to switch between the Auto-keying option and manual setting of keys was unexpectedly too long. And even if the participant located the controls his reactions were that the controls are really small to be used frequently. Therefore, better placement of the keying options could follow the placement of the playback controls in the Timeline component. This way the controls will be located more in the field of view of the user and the Auto-keying toggle size should be reduced in favor of Set key

button enlargement (figure 11.3.2b). Of course, these controls should be visible only if the keyframe view is enabled as in the previously proposed design.



(a) : Tested implementation of the keying options

(b) : Newly proposed implementation of the keying options

Figure 11.3.2: Keying options - redesign illustration based on usability testing outcome

- The usability tests have shown that the same transformation type animation overlap indication (Goal 3) is ambiguous and conflicting with the animation track selection indication design. Both actions/situations are indicated by the color change of the animation track's bar in the Timeline. The red color indication (the same transformation type animation overlap) mostly arouses suspicion about a problem in the participants, encouraging the participant to look up additional information. But when only two tracks are available in the Timeline this coloring becomes ambiguous. The suggestion on a design change would be to use just border highlighting to indicate the selected animation track and therefore color all of the tracks using the same color. Only when the same transformation type animation overlap occurs, tracks that are not possible to perform should be colored by red color.

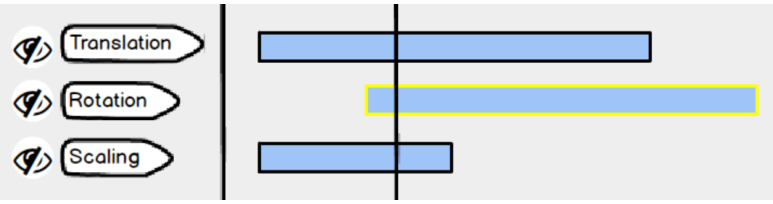


Figure 11.3.3: Newly proposed animation track selection indication design illustration (using yellow color)

- Many of the participants stated that they lack feedback about the preset animation parameter changes. In a real-life scenario, the user would be able to playback the animation track anytime when its parameters are set but immediate feedback would be a big improvement to the overall preset animation concept. One of the ways this issue could be resolved is using some kind of ghost object (a virtual copy of the animated object with low opacity) to visualize the final state of the animated object at

the end of the setup animation. This concept could be also furthermore enhanced by adding a labeled line with an arrow at its end to indicate the path of the object's animation as well as the distance or angle in the form of a label.

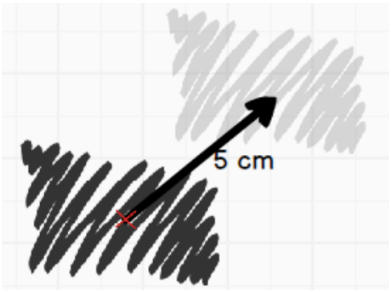


Figure 11.3.4: Newly proposed preset animation visualization design illustration

- The Animation explorer used for the animation track addition was frequently overlooked while the Add animation track button in the Timeline was used instead. This was caused by the simplicity of the application prototype and almost no knowledge about the application's UI from the participant's point of view. But even though when the object has selected the components that are enabled and therefore can be used should attract the user's attention by changing their state, coloring their content, etc.
- The cursor hinting for animation track extension or shortening was wrongly implemented in the prototype. This cursor hinting should appear when the user hovers the endpoints of the track not only when he already drags the track's endpoints. The same principle applies to similar features that provide cursor hinting.

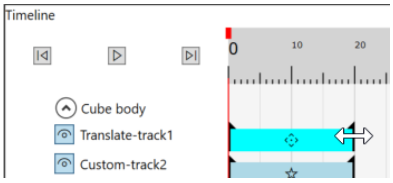


Figure 11.3.5: Cursor hinting when hovering the animation track bar

- When the preset animation has the possibility to set the target axis, selection of another object's axis is also provided. This feature was understood well by the test participants but to further improve this axis selection process a new design idea araised. A possibility to select the other object's axis right away in the 3D scene when the object is selected would simplify the workflow and reduce the need to shift the user's attention between the Animator component and the 3D scene. Therefore when the other object is selected its axes should be not only visualized but also clickable to enable this selection.

- The target axis selection used in the preset animations could be simplified based on some of the test participant's feedback. Using just the x, y, and z-axis toggles together with negative distance value as an example in the case of simple translation animation would enable the user to achieve the same goal as the proposed negative axis selection options.

Figure 11.3.6: Simplification of target axis selection illustration

- Finally, the keyboard shortcuts and meta-keys used for certain actions and tools were examined during each test. Due to the very diverging range of keys used by the participants no strict outcome on this topic was produced. However, the need to enable user modifications to the application's setup such as the keyboard shortcuts, meta-keys, or the overall workspace layout was obvious. Therefore this possibility should be definitely implemented in the workspace preferences for the user to modify certain keys he desires. This can be designed as a form-like page consisting of all the tools or controls and their corresponding key-binding (again inspired by Blender modeling software).

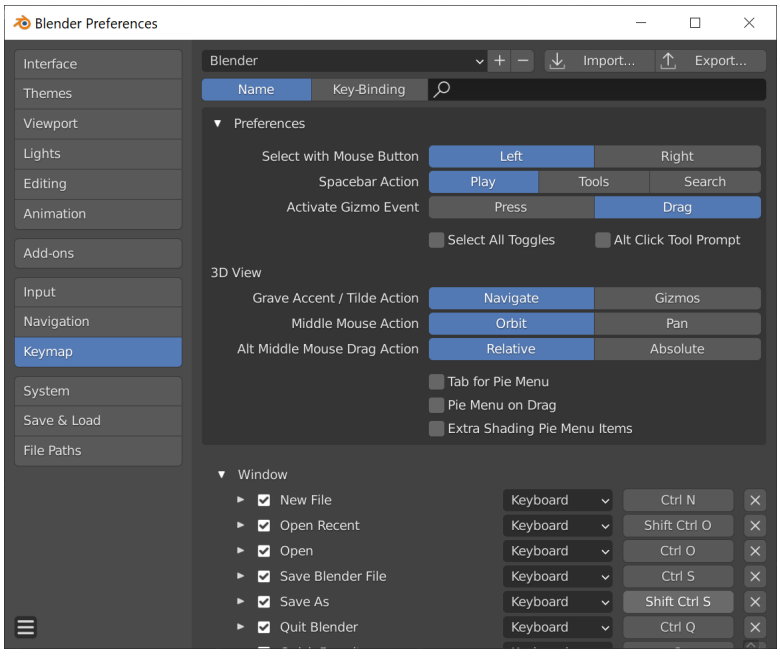


Figure 11.3.7: Blender Preferences - keymap

Chapter 12

Conclusion

In this thesis, the goal to create a new user interface design for augmented reality 3D modeler stated by the assignment and its requirements was achieved.

First, the necessary introduction to AR use in an industrial environment took place based on which the use-case scenarios were created to provide a foundation for the analysis of the existing Misterine company's product - Misterine studio and its user interface. Further, we analyzed other frequently used tools for 3D modeling and animation along with the best usability principles used in this field. The author studied these principles and frequently used practices to create a new design of the UI of the 3D scene workspace in a form of the low-fidelity prototype.

The low-fidelity prototype usability testing with 2 test participants selected based on the criteria set by use-case scenarios then revealed certain design issues such as placement of keying controls as well as it provided new concept ideas for example the snapshot saving option that were incorporated in the high-fidelity prototyping phase. With the high-fidelity prototype specified and implemented, another usability study with 6 test participants based on the user goals and use-case scenarios was carried out which results were precisely analyzed to evaluate the newly proposed UI design.

The newly proposed design of the user interface for the augmented reality 3D modeler builds upon the existing solution from Misterine. It aims to improve its drawbacks as well as to bring up new features and improve the user experience while working with the application. The usability testing confirmed its conceptual correctness. A few minor issues such as necessary relocation of keying controls to more accessible place or the need to better distinguish the track selection indication and the same animation type overlap indication were reported and their evaluation resulted in further recommended changes for future application development. The thesis thus creates a foundation for further development of the application based on the design's specification, the user interaction model, and the usability test outcomes.

12.1 Future Development Suggestions

Most of the suggested improvements for future development of the Misterine studio are mainly based on the user feedback during the testing phase and were described in detail in the high-fidelity prototype usability testing chapter.

Other than that, one recommendation that would bring even more possibilities of custom animation modification is to implement the so-called F-curve view to the Animator component mentioned in the prototyping phase. Implementation examples were shown during the SOA analysis phase. This feature would enable the user to even more precisely control each animation process and the object transformation process throughout the time of the animation.

The next addition could be a feature that would enable the user to nest or compose multiple animation tracks into one animation track in the Timeline. This feature would bring reduction of items shown in the Timeline and thus reduce the visual load on the user as well as simplify the workflow.

Furthermore, when it comes to the user interaction and the user experience while using mouse controller, keyboard shortcuts, and meta-keys it would be significant improvement to provide the users with various predefined sets of controls/key mapping corresponding to mappings of the state-of-the-art tools in the field. This feature is frequently implemented in the SOA tools and brings the user the possibility to use already known controls and keys of another software solution and thus improve the learning curve and user experience using another application.

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List of Abbreviations and Used Terms

AR Augmented reality.

HCI Human-Computer interaction.

IoT Internet of things.

SOA State-of-the-art.

UI User interface.

UX User experience.

W3C The World Wide Web Consortium.

Appendices

High-Fidelity Prototype Usability Study

Test Plan

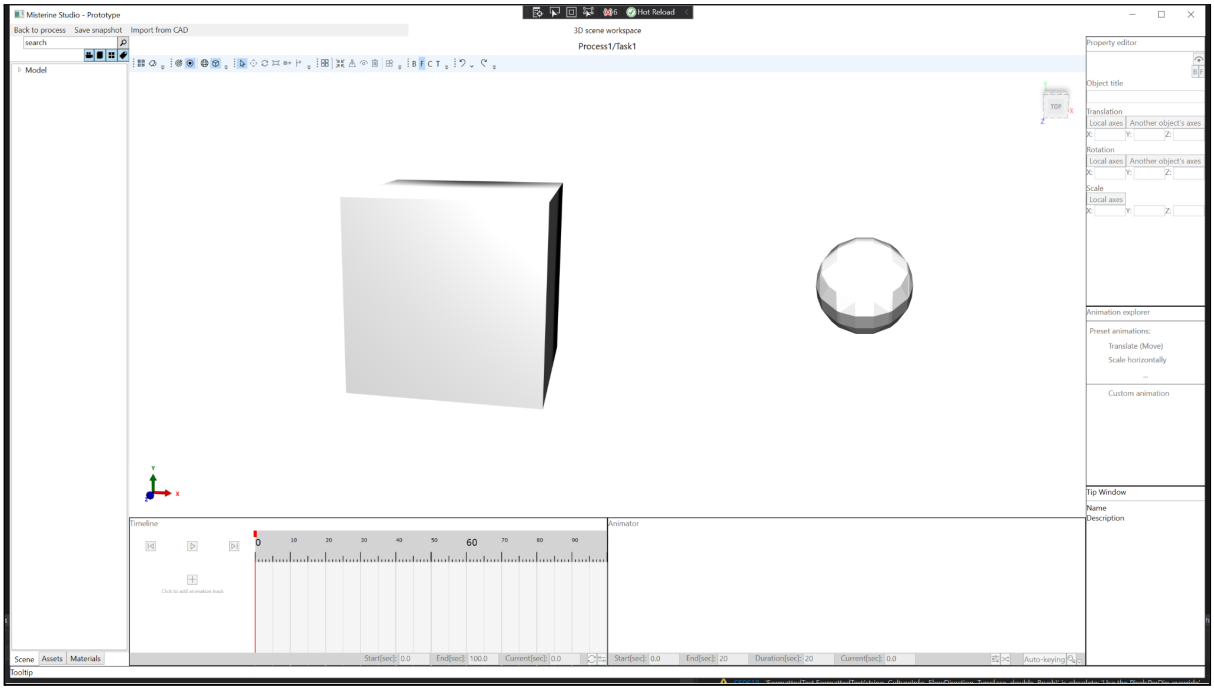
Test Reports

Test plan

Tested application and setup

The test object is the Misterine Studio - 3D Scene workspace prototype. This app is implemented as a Windows desktop application based on .NET Framework 4.7.2 and its Windows Presentation Foundation (WPF) open-source graphical platform. The prototype was developed using Microsoft Visual Studio Community 2019 (version 16.10.4) where the solution was build and the final executable used during the tests was produced.

Each test participant is provided with the app prepared on the desktop with mouse and keyboard controllers to satisfy minimal requirements established in the main text of the thesis. The desktop is running the operating system Microsoft Windows 10 Pro (version 10.0.19043, build 19043). A 24-inch screen with Full HD (1920x1080 pixels) resolution was used to view the application prototype. No additional application was run on the system during the testing phase.
Each test section starting point is the initial state of the application prototype (the application was always restarted) with no object selected or modified in any other way (the only exception is the “Test section 1” initial state for which animation is already added to the cube object). Moreover, each section may consist of multiple subsequent test tasks that conceptually bind together.



The test is mainly qualitative based on immediate user impressions, user experience, and understanding of the concept behind the design. During the test, the time spent on each task is also measured together with the error rate (number of misunderstood features or how many times the user got stuck) to provide additional test information. Each test is moderated and performed in person with the participant to provide richer insights.

The test will be concluded on 6 test participants (ref. How Many Test Users in a Usability Study?) while performing multiple quite small test tasks (ref. Turn User Goals into Task Scenarios for Usability Testing) to maximize the outcome and cover most of our usability problems. Based on our use case scenarios the participants were selected to fit the defined graphic designer persona. While the emphasis was also placed on a wide range of proficiencies and thus different design goals and approaches to get various opinions on the design.

Goals

The goal of this usability test is to confirm the design of the following features. Each goal number refers to the corresponding test task number.

1. **Animated objects indication** - the user should be able to quickly distinguish or filter out the objects that are or are not animated.
2. **Animation addition, Animation explorer understanding** - animation options should be easily accessible, therefore the user should easily locate the Animation explorer options or the Add animation track button in the Timeline when an object is selected, and thus animate the object
3. **The same animation type overlap indication** - two animations of the same type can not be satisfied at once, this situation is highlighted in the UI, the user should understand the highlighting of the overlapping animation track and the corresponding tooltip.
4. **Timeline and Animator animation parameter changes** - small changes such as the time span of the animation should be easy to do. The user should use the track's endpoints to do so (by dragging the endpoints) or the Animator input fields to change the exact time values.
5. **Custom keyframe animation, keyframing options** - contrary to the preset animations the custom animation at its base uses keyframes. Keyframes can be captured automatically when a transformation is made or manually. The user should be able to set a specific keyframe at a time point he desires.
6. **Trimming feature and its indication** - when the trimming is used the user should be able to distinguish the part of the animation track that is being cropped out or extended. So he is able to see and get back to the original state.
7. **Another object axes selection** - advanced animations need a transformation based on another object's axes. The user should be able to select the object and its axes when creating an animation.

Tasks

Participant info: Keep in mind that the test object is the application prototype, not yourself. During the whole test please think aloud. Before performing any action please let us know what do you expect to happen after.

Test section 1

Pre phase

Have a brief look around to familiarize yourself with the UI.

Task 1

Look up the objects that are animated.

Test section 2

Task 2

Create a translation animation of the cube object.

Task 3

Following the previous task, add another animation of translation to the object.

Task 4

Modify the timespan of the previously created animations.

Test section 3

Task 5

Create a custom animation of the cube object using manual keyframing.

Task 6

Extend the timespan of the animation without disturbing the created animation and its keyframe layout (using the previously created animation with keyframes).

Test section 4

Task 7

Create a translation animation of the cube object. Do not use its local axes to base on the translation.

Notes

Add to each test:

- User profile of each test participant (education, experience, industry, age, ...)
- Specific test conditions (time, day, place) of each test

Additional test outcomes:

- Participants were also asked for certain keyboard shortcuts and meta-keys they would use for some of the tools used during the tasks. Unfortunately, there was no conformity on the keys used as well as throughout the SOA analysis. Therefore these results are not taken into account. Nevertheless, some participants stated that it is important for them to be able to modify the shortcuts in the preferences of the software used.

Usability test #1

The first test was concluded on the evening of 22.8.2021 while the testing itself started at 7 pm. The test participant was provided with the desktop setup in an office-like space of a living room.

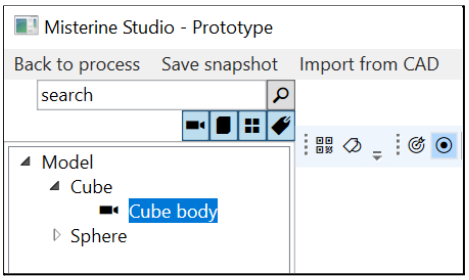
Test participant profile

Test participant P1 is 27 years old male and lives in one of the Czech Republic's biggest cities. He graduated from industrial engineering several years ago. Nowadays he focuses on industrial design and works daily with 3D modeling tools to create automized algorithms for the design of medical devices. P1 has roughly 5 years of experience working with modern CAD software such as Creo or Autodesk software. Principles of video editing and animation are known to him as well.

Test report

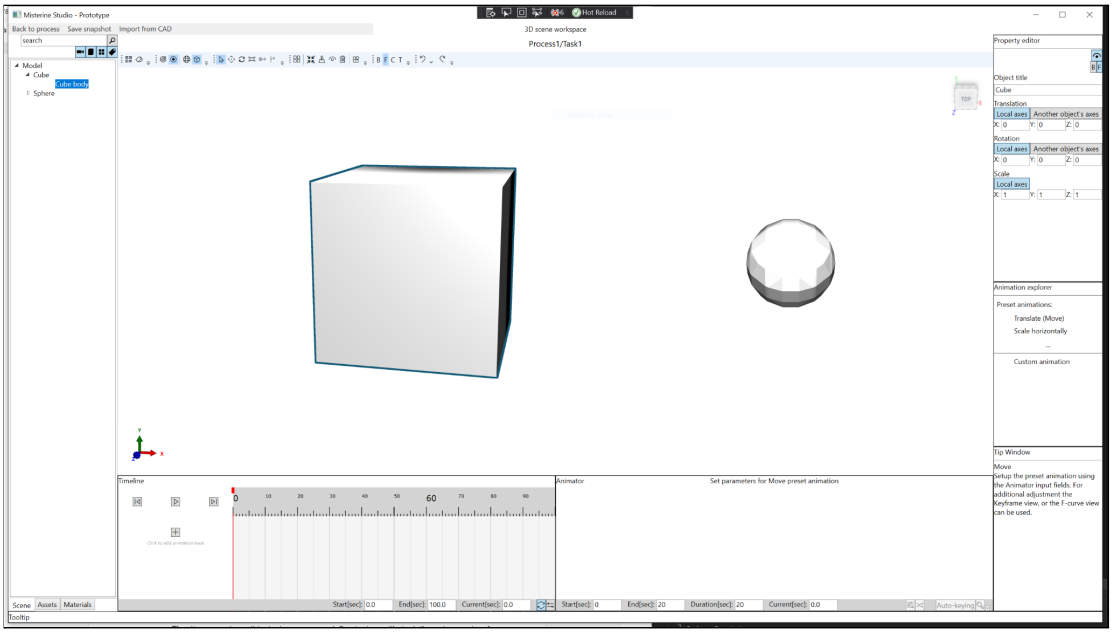
- First overall impressions of the application prototype and the UI component layout were understandable for participants P1 and he was able to familiarize himself pretty quickly and recognized most of the UI features well.

Task 1. Starting with task 1 the participant briefly looked around and localized the model items in the Scene explorer while discovering the animation label (camera icon) next to the object. He understood well that the label states that the object is animated and was further asked by the moderator if he can somehow filter out the animated object. This took again just a moment when he discovered the filter toggles and successfully completed the additional task. He was satisfied with the behavior, but he just stated that the camera icon (animation label) could be a bit bigger to easily recognize the pictogram's shape.



This task took roughly 3 minutes including short feedback from the participant.

Task 2. Moving on to task 2 he was a bit hesitant when he selected the object in the scene. He expected to see immediately the transformation controls attached to the object in the scene, that he could drag and thus transform the object. Participant P1 is used to this behavior from other software but a brief explanation from the moderator side got him quickly back on track.



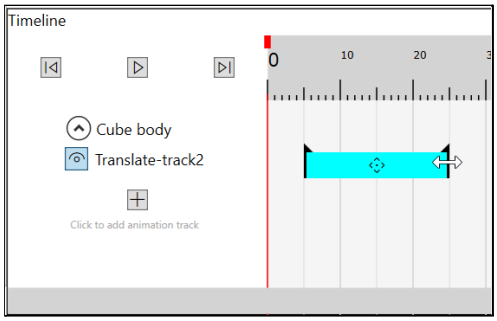
Following a brief hint about a missing timeslot for the animation from the moderator he quickly realized that he needs to add a so-called animation track in the timeline. This got him to discover the Add animation track button providing a preset animation of translation which he then flawlessly used and set up.

Due to the partially misunderstood process of the animation creation, this task took about 10 minutes while consisting of one major error (the workflow understanding) and one minor error (the expected transformation controls).

Task 3. Adding additional animation to the object during task 3 was a quick and easy job for the participant showing good learnability of the prototype's concept. Moreover, he was asked if there is any other way except the Add animation track button in the Timeline to add the animation track to the Timeline. After that, the participant looked around the UI and located the Animation explorer with no problem. The same transformation type animation overlap indication was also clear to him. Even before reading the tip provided, he supposed the indicated problem by the red color of the conflicting track.

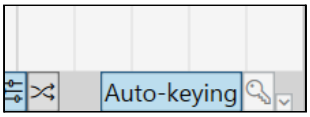
This task took approximately 5 minutes without any major nor minor problems.

Task 4. Task 4 based on the previous tasks also followed the flawless run. Participant P1 used the time input fields in the Animator to modify the animation's timespan first. The interactivity of the time input changes and the animation track bar in the Timeline was very satisfactory to him. Later on, he also successfully tried to extend the animation track by dragging one of its ends in the timeline. The implemented behavior he expected. Just a minor note he had was the visibility of scaling cursor type which he would prefer to be available as soon as the user hovers above the track's endpoints and not only when dragging.



The time spent on this task was around 2 minutes with just the minor note of extension cursor availability.

Task 5. Moving on to the custom animation creation the participant went again first to the toolbar area to transform the object as it was during task 2. After the selection of the object, he selected the translation tool and got a bit stuck while not knowing how to record the transformation. After a while, he remembered the task 2 scenario and realized that he needs the animation track to be added first. This brought him down to the Timeline where he chose the custom animation option. Other steps went as expected with no problem. The only note he had to the keyframe setting options was that the Set key button is quite a small one but is used very often.



To finish this task took about 5 minutes. Again, one major flaw in the workflow was when the participant wanted to animate the object while not having any animation track available (and selected) in the timeline.

Task 6. Before task 6 was performed the participant was acquainted with the track scaling and trimming features and how each of them affects the track's keyframes. Based on the knowledge, P1 proposed to use the Ctrl key while dragging one of the endpoints of the animation track to trim the track and achieve the goal of this task. Therefore he was suggested to use the implemented option using the Shift key. The visual interpretation of trimming was clear to him (extension as well as shortening) and he did not find it any disturbing.

Overall task time was 3 minutes, with no issues.

Task 7. In the end, the use of another object axes to do the transformation was tested. This task was also one of the flawless. First, he was asked to set an axis for a preset animation and later on for any transformation in the scene. Both approaches were understandable and easy to perform for him. He also showed a vastly better orientation in the UI contrary to the first use during the initial tasks.

Roughly 5 minutes was the time spent on this task, containing the animation addition.

Summary

As a summary the impressions of participant P1 were really good, he understood the preset animation setup as well as the custom animations using keyframes. Overall, no major flaws during the test were discovered except the workflow misunderstanding that the participant later accepted and familiarized with. Even though some minor changes to the UI could be proposed such as Set key button (Animator) and Animation indication label (camera icon,

Scene explorer) enlargement as well as extension cursor indication already on hover (no just when dragging the track’s endpoints).

Usability test #2

The test was concluded at 11 am. 23.8.2021. The test participant was provided with the desktop setup in an office-like space of a living room.

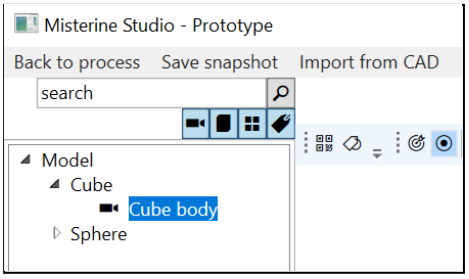
Test participant profile

Test participant P2 is 55 years old male educated in construction engineering and living in one of the biggest cities of the Czech republic. He has years of experience designing civil infrastructure, making visualizations, etc. in Autodesk software and Bentley software. Throughout his career, he also encountered 3D modeling and animation, so the basic principles needed for our use case are well known to him.

Test report

- The first design impressions were good, the participant managed to localize and describe the basic functions of all the UI components and tools correctly and their layout seemed reasonable to him as well.

Task 1. Starting with the discovery of animated objects the participant first selected the objects and looked in the Timeline to see if an animation track is present. Since this is also a possible way but not the most efficient in a case of a complicated 3D model the moderator encouraged P1 to look for any other option to distinguish the animated objects from others. It took some time but eventually, the participant discovered the camera icon indicating the animation of the object in the Scene explorer but he stated that it was kind of hard for him to discover that the icon is actually a camera pictogram and not any other shape.



Therefore he would prefer to make this labeling bigger and more significant. He also found and used the filtering options with a satisfactory result after.

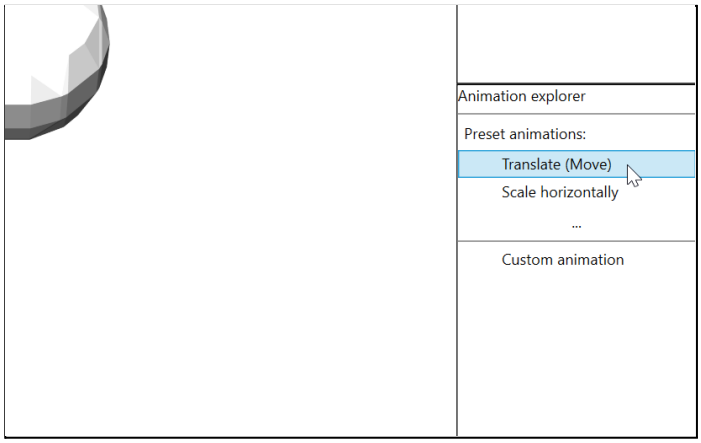
Since an alternative way to discover the animated objects was taken by the participant at the beginning the test took approximately 5 minutes. The only issue found is the icon size for the animation indication in the Scene explorer.

Task 2. The participant again started with the discovery of the transformation tools in the toolbar. Later on, he moved his focus to the Timeline where he clicked the Add track button. At this point, he realized that he does not need to do any transformation but he can use the preset animation of Translation (Move). The following preset animation setup was straightforward for him, he understood the inputs well and managed to successfully complete the task.

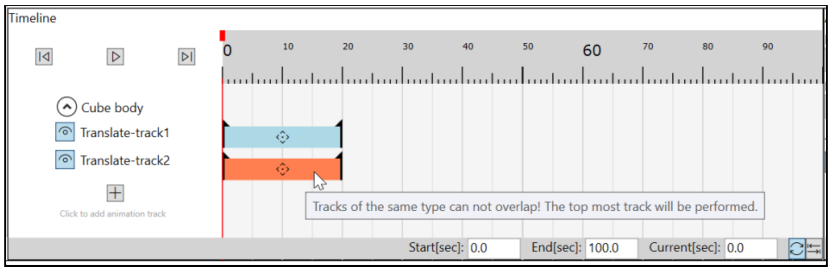
He was satisfied with such simplification based on the preset animation but he

mentioned that he would like to see some feedback on how the object will be animated based on the set parameters. This task took about 7 minutes.

Task 3. Continuing with task 3 the first thing that came to the participant's mind to add another animation was to copy and paste the already created one and then modify it. Since this is also a valid option but not desired for this task P2 was asked if there is any other way to add another preset animation. Locating the Animation explorer took some time, the participant did not expect to find the options in two places simultaneously.



But following animation addition and its behavior was fine to him. At this point, the same transformation type animation overlap indication (red-colored animation track bar) was triggered. First P2's impressions were that animation tracks are just differentiated by color so he was encouraged by the moderator to investigate further.



This caused him to discover the tooltip and also the Tip window where the correct reason for the coloring was mentioned. His reactions were positive mainly due to the Tip window availability for novice users but he would prefer to use different representations or indications of the overlapping tracks since the track selection indication is done the same way (color change).

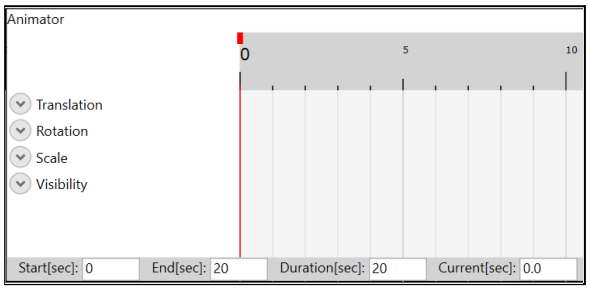
The task was completed roughly in 10 minutes but a short discussion based on the task's issues followed. His proposal was to stick to the red coloring of the overlapping tracks but to use just border highlighting for the track selection indication to distinguish these two situations.

Task 4. The animation track's timespan modification was performed by P2 without any issues. Both options (extension by dragging, precise time input fields) were located and used with expected behavior.

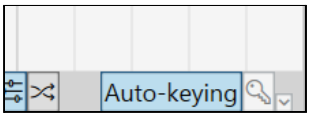
The task was finished quickly in about 3 minutes. The participant was really pleased by the immediately visible interaction of the track's parameter changes.

Task 5. The custom animation was added flawlessly throughout the use of Add animation track button. At this point, P2 expected to see initial keyframes at the beginning of the empty track in the Animator, but he also mentioned that this was just

his expectation and maybe it makes sense to add the keys once other keys are captured.



Nevertheless, this is also a point where the participant got stuck, he knew the custom animation workflow well, but he was not able to quickly locate the keying options.



Following a hint from the moderator, he turned off the Auto-keying and completed the task as expected.

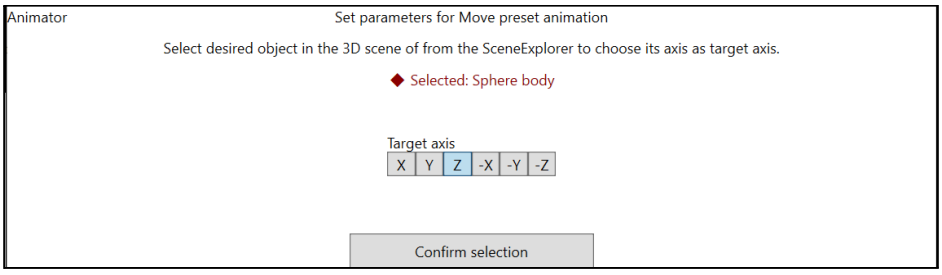
The task took approximately 10 minutes since P2 got a bit stuck when locating the keying options. This would be a major issue since he was not able to complete the task at this point. Moreover, he proposed to locate these controls to a much visible place in the top-left corner of the Animator component where he would probably find them.

Task 6. As in all test cases, the participant was introduced to the concept of scaling and trimming the animation track before the task was performed. He did not have any suggestions on what meta-key to use to enable the trimming option so he was provided the information to use the Shift key. P2 performed the action and well understood the outcome. He was also satisfied with the fact that he can see the extended or cropped-out portion of the track.

This task took 3 minutes to complete with no issues.

Task 7. This task has shown good learnability of the design. The participant quickly added the preset animation and straightaway moved his focus to the target axis setup in the Animator. Another object's axis selection phase was understandable to him and he intuitively selected the object and picked his axes. The same applies to the case of the Property editor when he was asked to do a precise rotation of the Cube object around the Sphere object.

While completing the task in 5 minutes, P2 mentioned that it is crucial for him to see the object he selected (respectively also the selected axis) which the "Selected" label in the prototype provided.



Summary

In a conclusion to this usability test, the overall satisfaction of the participant during tasks and his impressions were positive. No major usability issues were found except the location of the keying options in this case. The keying options placed in the corner were not located by P2 so relocation to the top-left corner of the Animator component where the controls would be more accessible is a possibility. One minor issue to address based on this test would be to enlarge the animation label indicating animated objects in the Scene explorer. Another improvement could be a visualization of preset animation setup, mainly the object transformation using for example a labeled arrow showing the direction and distance the object will reach at the end of the animation together with a ghost object at the end of it. Moreover, the same transformation type animation overlap indication interferes a bit with the animation track selection indication, this could be resolved as the participant suggested by just highlighting the border in the case of animation track selection.

Usability test #3

The test was performed 23.8.2021 at 7 pm. The test participant was provided with the desktop setup in an office-like space of a living room.

Test participant profile

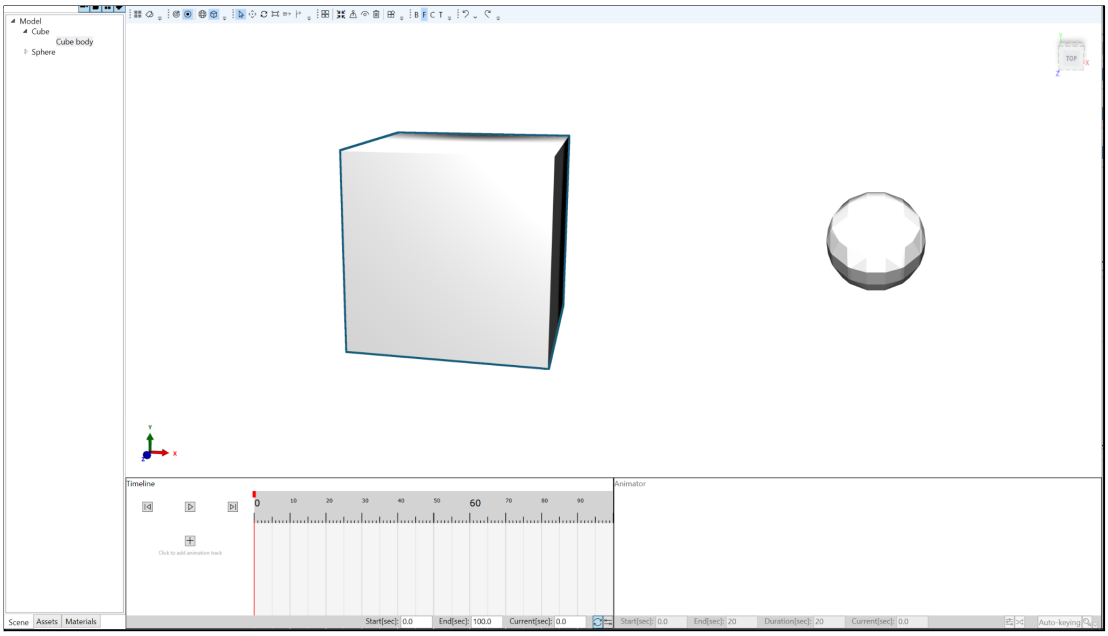
Participant P3 of this test is 24 years old female living in Prague, Czech republic. She is a university student and focuses on 3D graphics, design, and animation. She is familiar working with Blender, Autodesk software, and Houdini modeling solutions as a part of her part-time job as a graphic designer.

Test report

- During the first look at the UI prototype, the participant was satisfied with the layout, she understood the logical separation of each component and the tools. The only unexpected thing for P3 was the size of the space taken by the Timeline component since she is used to working with much smaller timeline-like components.

Task 1. The first task was simple for the participant, her first suggestion was to select the object and see the animation in the timeline. Moreover, she was asked how would the goal be achieved if there were many more objects in the scene. At this point, she located the animation label (camera icon) next to the animated object in the Scene explorer as well as used the filtering options correctly later on.
The task was performed in about 4 minutes following the concept workflow.

Task 2. P3 was a bit hesitant at the beginning of this task, this was probably caused by misunderstanding the preset animation concept and therefore she searched for keying options right away in the Timeline component to be able to start the animation creation process, even without an animation timeslot (track) added.



Throughout the search, she located the Add animation track button on which she clicked later on discovering the animation track options. This made her realize and grasp the concept but even though a brief explanation from the moderator followed. The Animator use and the preset animation parameter setting were then flawless and clear.

Completion of this task took approximately 10 minutes while revealing one major issue. Understanding that the timeline consists of several animation tracks (timeslots) representing partial animations and these tracks that can be modified (parameter changes, keyframe capturing, etc.) using Animator is crucial.

Task 3. When the concept was understood by P3 the animation creation was no issue at all. Later on, she also located the secondary option (Animation explorer) to add an animation track to the Timeline. The same transformation type animation overlap indication that triggered at this point was immediately clear to her. First, she suspected something wrong with the track which caused her to search for a tip (the track's tooltip) which she quickly located. Moreover, she was asked if the information can be also gathered somewhere else. While the following search of the Tip window component was successful and very pleasant for her.

Nice feedback on the implementation of the useful tooltips followed and the task on its own took around 3 minutes.

Task 4. Modification of the timespan was straightforward, the first thing P3 did was to drag the endpoints of the track. She also realized the simultaneous changes of the track's parameters in the Animator and continued by trying to change the timespan this way too.

This task took just 2 minutes.

Task 5. Knowing the concept from the beginning of the test the participant added a custom animation using the Add animation track button in the Timeline. Key setup and object transformation are very familiar to her so no issue was encountered during this phase. First, she used the Property editor to set up the state of the object to capture by keyframes. Later on, P3 was asked if there is any other option to do so which turned her attention to the Toolbar's transformation tools as expected.

The participant's impressions were pleasant, the behavior and animation creation process workflow was as expected. To complete this task took roughly 5 minutes.

Task 6. The animation track scaling and trimming concept was clarified to the P3 at the beginning of this task. Since she is used to having a fixed animation time and creates just the animation that fits this time range the feature to edit the timespan of an animation when the animation is already created seemed not useful. Nevertheless, she understood the idea and performed the task with no issues (with a hint to use the Shift key to enable the trimming). The colored extended or cropped-out area was self-explanatory for P3.

The time spent on this task was around 3 minutes.

Task 7. This task was also one of the non-problematic. Both approaches, the preset animation target axis selection as well as the Property editor's Another object's axes selection were understandable and easy to perform. The object selection was clear and with satisfactory feedback. She also noted that it would be nice to be able to just draw a custom axis in the scene if needed.

About 3 minutes was the time to complete this task, containing the preset animation addition.

Summary

To summarize the test P3 had no problems complete these tasks. There was just one major misunderstanding of the concept at the beginning but with immediate explanation, the concept was clear and easy-going for the participant. There was no major issue furthermore and the participant’s expressions were pleasant.

Usability test #4

The test with participant P4 was concluded on the evening of 23.8.2021 at 8 pm. The test participant was provided with the desktop setup in an office-like space of a living room.

Test participant profile

P4 is 24 years old male student living in Prague, Czech republic. Throughout his studies of information technology at university, he has a part-time job as a full-stack web developer. The graphical design or modeling itself is not the main subject of his studies nor the work but belongs to one of his free-time hobbies. P4 is familiar with Autodesk software (mainly Fusion 360) and uses its tools to model small tools, parts, accessories, etc. that are later used for 3D printing.

Test report

- First overall reactions on the layout and the component features of the prototype were positive and matched the expected look of the tool. He roughly understood the individual tools and purpose of each component.

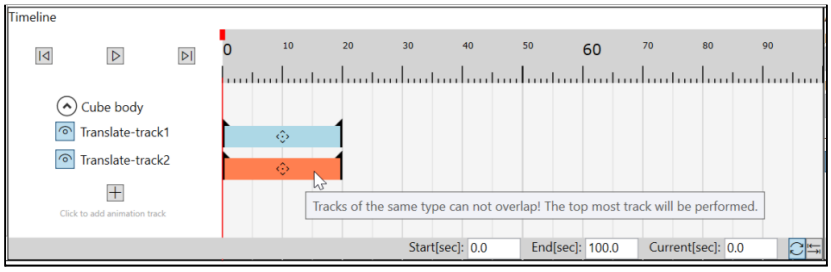
Task 1. During task 1, P4 first looked around and selected the objects one by one. This gave him the information desired since he saw an animation track in the Timeline of the animated object. Moreover, he was asked by the moderator if there is any other way how to achieve the goal. After a while, the participant located the animation label (camera icon) indicating the animated object in the Scene explorer. Furthermore, the filter toggles were located by himself which he found very useful and intuitive.

The task run with no issues and was completed in 5 minutes.

Task 2. Animation creation was flawless as well. The participant used the Animation explorer to add the preset animation. Without any additional instruction, he started to speak about modifying the animation track's timespan while using the time input fields or dragging the track's endpoints. Therefore he was asked to perform such action to further confirm the understanding and compare the behavior with his expectations. Furthermore, he stated that it would be a nice-to-have feature to visualize the preset animation based on the parameter setup somehow.

The original task took approximately 5 minutes while the additional modifications were another 3 minutes. No problems were encountered, on the contrary, the user showed a great understanding of the design and therefore task 4 was already performed as a part of this task.

Task 3. For this task, the user was asked to use another option to add the animation track to the timeline. Therefore he quickly localized the Add animation track button in the Timeline that he then use to add a second animation track to the object. At this point, the same transformation type animation overlap indication was triggered. While he quickly found the track's tooltip indicating the problem he mentioned that the color change on its own did not arouse any suspicion in him about any problem with the track.

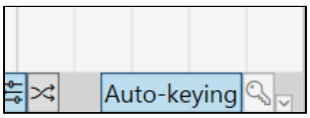


But when we added multiple non-conflicting tracks to the Timeline the coloring was more clear to him.

The only issue in this task was the same transformation type animation overlap indication which is self-explanatory only when more than 2 or 3 different animations are present in the Timeline. The task took 4 minutes.

Task 4. Skipped (due to task 1).

Task 5. The beginning of this task was fluent the participant added the custom animation track using the Animation explorer and continued with a timepoint setup. At this state, he hesitated since he was not able to locate the keying tools.



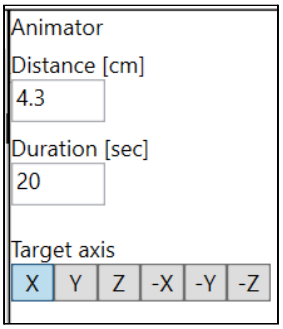
Following the hint to investigate the Animator component more he eventually found the controls and successfully completed the task. The workflow matched his expectations and the result was satisfactory.

To complete the task took about 10 minutes while the user got a bit stuck in the middle of the work. The major issue here was the placement of the keying options that he was not able to locate on the first run.

Task 6. Before this task, the participant was acquainted with the track scaling and trimming features and how each of them works. Since no opinion on a meta-key used for enabling the trimming option was given by P4 he was suggested to use the Shift key while dragging. Doing so it was visible that he really likes the visual interpretation of the trimming extension or crop. He also mentioned that it is nice to have such a “buffer of changes” that he can then confirm or revert.

Time spent on this task was 5 minutes while the user tried many combinations himself and had very pleasant responses.

Task 7. In the end, another object’s axes selection feature was tested with the participant. He quickly added a new preset animation track to the Timeline showing that he got already familiar with the design after a few previous tasks. He clicked the Choose another object’s axis button and followed the object/axis selection with no issue. The selection went as he expected, he would only prefer to use just the x, y, and z-axis while using negative parameters such as distance to achieve translation in opposite direction.



No problem occurred also when he was asked to do any transformation desired. He found the axes toggles in the Property editor and set up the other object.
The task went flawlessly in 6 minutes.

Summary

To sum up the usability issues and feedback from this test, the participant very well understood the concept and the application's behavior was as he expected. The only key issue was the placement of keying options which are rather hidden in the corner. Moreover, he had suggestions for the preset animation tracks to use just x, y, and z target axis options to even more simplify the selection and use the negative distance value instead to achieve translation in other direction (this could be of course analogously applied also to the other transformations, not just translation) and to add a feature that would visualize the animation as the track's parameter setup changes.

Usability test #5

The test was concluded in the afternoon of 26.8.2021 at 5 pm. The test participant was provided with the desktop setup in an office-like space to perform the test.

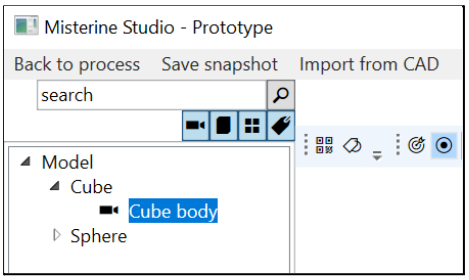
Test participant profile

Participant P5 is 29 years old male that lives in Prague, Czech republic. He graduated from industrial engineering and specializes in industrial engineering design also throughout his work career so far. His daily work consists of documentation creation, 3D modeling, and simple animation creation of industrial machines. P5 has experience working with Autodesk software, Solidworks software solutions, and Creo (mainly throughout his studies at university).

Test report

- The first participant's reactions to the design were positive, he familiarized himself quickly with the layout which followed patterns he knew from his practice.

Task 1. Right from the beginning of the task the participant intuitively clicked the Cube body to select the object while revealing its animation in the Timeline. He also clicked the Sphere body then to recognize that this object is not animated. When he was asked to find another way to find out if an object is animated he took some time to look around. Unfortunately, even if the Scene explorer items were expanded he did not localize the label indication (camera icon) next to the object's label.



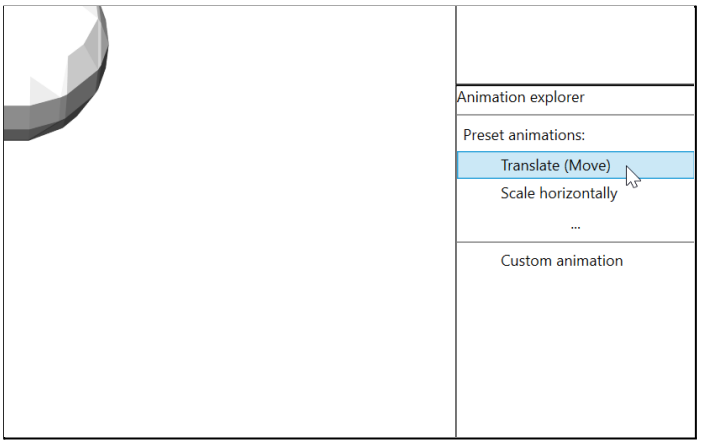
To give the participant feedback the label indication was shown to him. P5 then stated that he just did not see the exact shape of the symbol and therefore did not pay attention to it. At this point, the participant on his own started to click on the filter toggles which caused satisfaction while he also flawlessly understood their function.
The task took about 7 minutes while revealing a problem that the animation label indication (camera icon) should be more vibrant and clear for the user to really recognize it.

Task 2. The participant already knew from the previous task that the animation track is shown in the Timeline. Therefore he immediately moved his focus to the Timeline after selecting the object. He seamlessly used the Add animation track button to add the Translate (Move) animation. Moreover, P5 used the Animator input fields to set up the animation as well as to edit its time properties. At this point, he really appreciated the Tip window which described what and where should be modified to achieve the task's goal. He also mentioned that he frequently uses such

features and really likes it if the tips of hints change frequently and guide the user step by step through the process.

The task with no issues took approximately 5 minutes.

Task 3. Throughout the task, P5 was asked to add the same animation as in the previous step but using another method. Therefore the participant got a bit stuck at this point looking for another way. He suggested using custom animation using precise transformation and keyframing, the discovery of the Animation Explorer took a bit longer but eventually also this component was located and used with no problem.



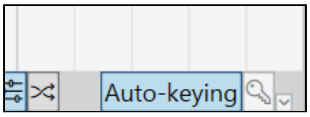
After the task, P5 said that he would like to move the whole component panel on the right side to the left side next to the Scene explorer which would minimize his eye movement and therefore he would probably also locate and use the Animation explorer better. When the same animation was added to the Timeline the same transformation type animation overlap indication was triggered. The participant did not say anything about the situation so he was asked by the moderator. P5 first intuitively stated that the tracks are overlapping and later on also discovered the corresponding message that confirmed his expectation.

Based on this test the availability of the component layout modification could be crucial for some users. To finish the task took roughly 8 minutes.

Task 4. Modifying the timespan of previously created animation went seamlessly. P5 already used the time inputs in the Animator previously so he was asked to imagine any other way to achieve the same goal. As a result, he dragged the endpoints of the animation track as well as the track itself to a different timepoint.

The timespan modification went as expected and the participant was satisfied with the result. 3 minutes took P5 to finish this task.

Task 5. New track addition was not complicated for the participant, later on, he suggested doing the transformation of the object using tools in the toolbar or the Property editor's transformation fields. After transforming the object a key was recorded in the Animator, due to the Auto-keying option checked.



When this happened P5 realized that this was not the result and therefore he successfully looked up the buttons in the Animator to disable the Auto-keying, moved in time, and set a manual key. After all, the animation using manual-keying was quite quickly created by the participant.

The task took about 5 minutes and its result was satisfactory. Nevertheless, the outcome is that the keying options should be probably more significant for the user to locate them immediately when animating.

Task 6. The trimming option was understood well by the test participant but he did not have any real experience using such a feature. Therefore he was suggested to use the Shift key to enable the feature. He then took the mouse controller and extended the animation track while pressing the Shift key. He was positively surprised by the visual feedback which told him what proportion of the track he added or cropped out. Furthermore, he was asked by the moderator if he can somehow revert the action. The first thing that P5 suggested to use was the Undo button in the Toolbar which is one of the correct options but he has also found the Confirm/Revert trimming options in the track's context menu later on.

Even though the participant did have any real experience using such a feature before he understood the concept well and was able to achieve the task's goal easily and quickly (in about 4 minutes).

Task 7. Another object's axes selection went flawlessly. The participant understood well both options (the preset animation's axis selection as well as the Property editor's axes selection). He very intuitively picked the other object and was satisfied with the overall UI behavior during the process.

This task took approximately 5 minutes while no issue was revealed.

Summary

No major issues were revealed by this usability test. The participant expected the implemented behavior most of the time. The only crucial feature from his point of view would be the customizability of the workspace and its component layout. Another important customization would be the keyboard shortcut settings since P5 is used to modify these as well to his own preference.

Usability test #6

The test was concluded on Monday 26.8.2021 at 6 pm. The test participant was provided with the desktop setup in an office-like space of a living room and a quick introduction to the topic as well as in the previous test cases.

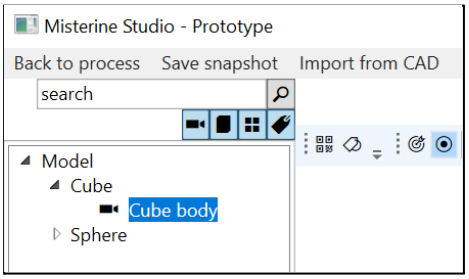
Test participant profile

Participant P6 lives in one of the Czech Republic's biggest cities. He is 27 years old and recently graduated from university where he studied industrial engineering while focusing on modern building design. He works in the field as a heating, ventilating, and air conditioning designer for modern buildings for several years as well. He has broad experience working with Autodesk software (such as Revit and Inventor). P6 also does some photo and video editing as part of his hobbies, thus animation principles are well known to him.

Test report

- The participant was satisfied with the initial layout. The layout follows his expectations based on his knowledge and habits. The only note he had at this point was that modifiability of the layout could be crucial for some of his work colleagues that use completely different layouts than he is used to.

Task 1. The task 1 process was very similar to the previous test case. P6 started with a selection of the objects which revealed the animation track in one of the object's timeline. Moreover, he was asked how he would achieve the goal if he had a far more complicated 3D model loaded. In a while he located the animation indication label (camera icon) next to the object in the Scene explorer, he also toggled the filter options a few times.



As a result, P6 was satisfied with the indication, knowing its meaning right away with no hesitation.

This task took roughly 4 minutes and no major issue was revealed.

Task 2. During task 2 participant did not show any hesitation. P6 selected the object and headed to the Timeline to click on the Add animation track button where he selected the correct animation option. The UI feedback was as expected, he correctly used the preset animation parameter input fields to set up the animation to his desired state. Without any additional impulse from the moderator, P6 started to try other features by modifying the timespan of the animation using the dragging option as well as the precise inputs. Therefore the goal of task 4 was already covered at this stage.

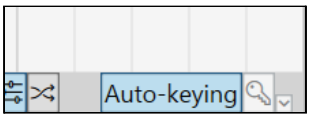
Due to extensive work done during the task, the completion of the task took 7 minutes (of which the additional steps took approximately 3 minutes).

Task 3. For this task, the participant was asked to add the animation using any other input method. P6 looked around the UI and quickly found the Animation explorer component containing the same preset animation options. After the animation track was added he noticed the track's color change, the first idea that came to his mind was correct. He got the purpose of the same transformation type animation overlap indication. Additionally, he also added a preset animation of scaling which even more confirmed his understanding. He only noted that this could be a bit confusing with the track selection indication which is also done by a color change in this case.

The overall process went flawlessly in 5 minutes. The task's outcome would be to rethink the design of animation track selection indication versus the same transformation type animation overlap indication.

Task 4. Skipped (due to task 1).

Task 5. The use of the custom animation was almost with no problems. But one problem repeating among most of the test was again that the keying options was quite hard to find for the participant.



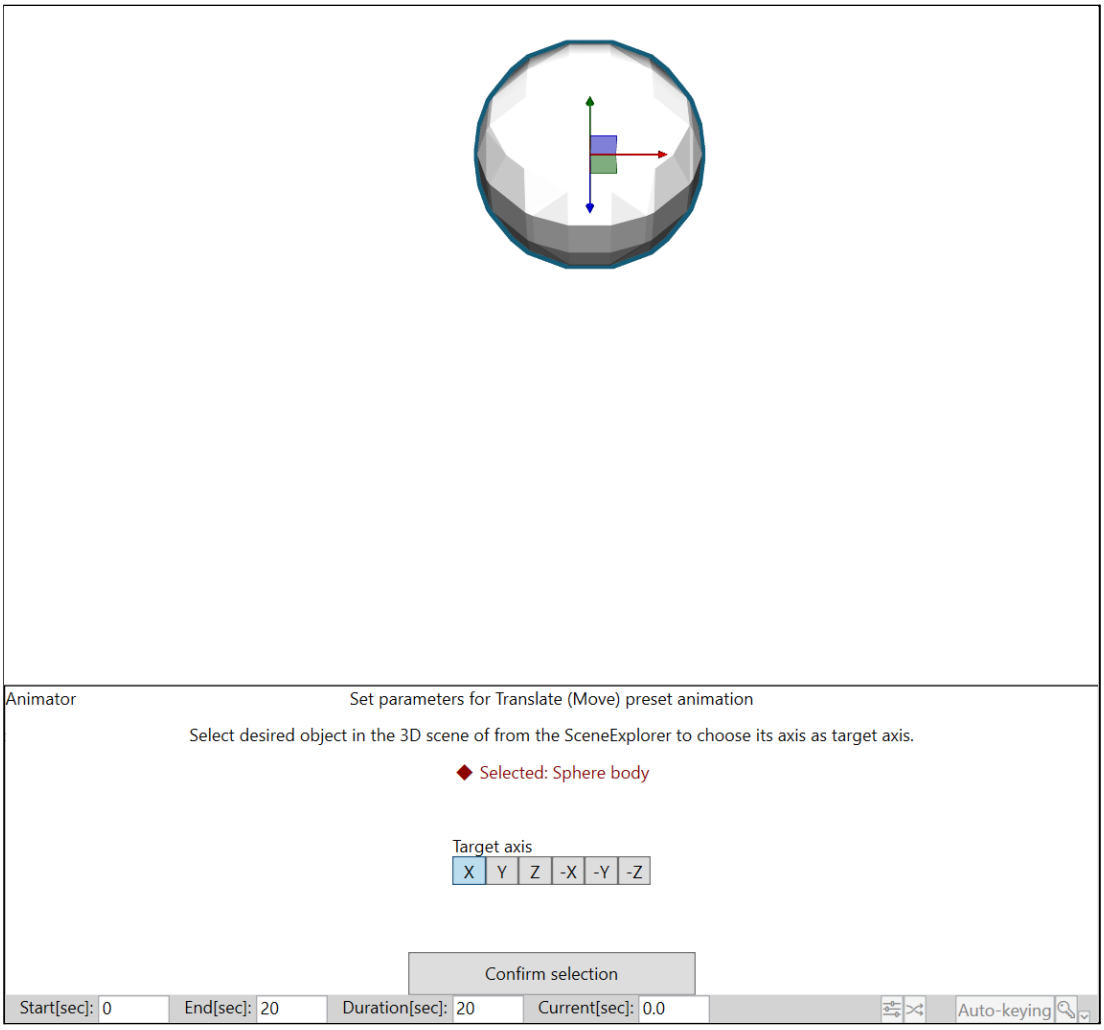
P6 eventually found the controls and used them the expected way but the time to locate the controls was quite long and caused a bit of dissatisfaction. His opinion was that the controls are small and completely in the corner so he really needed to look them up.

The task again showed the wrong placement of the keying options in the Animator. Other than that no issue was found during the task that proceeded for 6 minutes.

Task 6. The overall concept of trimming versus scaling the animation track was described to the participant. P6 grasped the idea and need for such function. Following animation track modification based on a hint to use the Shift key to enable the trimming function went seamless. The participant appreciated the visual feedback in form of different colors for the extension and the shortening (crop). Later on, he also tried out the confirm and revert trimming options located in the animation track's context menu.

This task took about 5 minutes.

Task 7. P6 first used the preset animation to try the axis selection. The process went as expected. The only not implemented feature the participant noted was a possibility to select another object's axis straight away by clicking on the axis in the 3D scene when the object is selected. This would be a nice-to-have feature since the user would not have to shift his attention between the Animator and the 3D scene.



Other than that, P6 was satisfied with the result and the feedback label of the selected object which axes should be used. The Property editor another object's axes selection outcome was analogous and no major issue was found.
The task was finished in 6 minutes while bringing an idea about improving the axis selection by enabling clicking on the desired axis right in the 3D scene and therefore simplifying the selection process.

Summary

During the test, no major issue that would have an impact on the usability of the whole application was found. Nevertheless, the animation indication label (camera icon) should be more vibrant and eye-catching. Also, the design of animation track selection indication and the same transformation type animation overlap indication should be made more distinctive, using for example just border highlighting in the case of the animation track selection indication. Moreover, improving the process of another object's axis selection in the case of preset animation based on task 7 would improve the user experience and the workflow as well.

External Attachments

Low-Fidelity Prototype

- low_fi_prototype.pdf (low-fidelity prototype mockups)

High-Fidelity Prototype

- high_fi_prototype.zip (high-fidelity prototype source code and resources)