Virtual Reality
Winter Term 2021/2022

Final Project

The final project (graded separately and awarded additional 1.5 ECTS) requires you to apply the obtained theoretical and practical skills of the course in the design, implementation and presentation of an individual small research project. In particular, you will be asked to develop a concept, come up with an effective and efficient implementation and present your results in a concise talk.

Group work in pairs of two is encouraged. Depending on the complexity of your idea (or if you choose any of our larger group topics), working in teams of up to 4 students is also an option.

Claim a topic on Moodle from **7 February 2022, 9:00 am** until **11 February 2022, 11:55 pm**.

You are required to submit this assignment by **17 March 2022, 11:55 pm**. Similar to the VR lecture assignments, compress your complete application directory to a .zip file and upload it on Moodle. Furthermore, you will be asked to present and discuss your results on **18 March 2022**. We will provide scheduling tools for your individual presentation time slot on Moodle a week prior to the presentations. Later submissions and presentations are only granted on special request with a significant reason.

Each group can request one individual consultation. Days available for a consultation are **25 February, 4 March or 11 March 2022**. To request a timeslot, send an email to **sebastian.stickert@uni-weimar.de** and **ephraim.schott@uni-weimar.de**.

Support via Moodle and Email is open at all times. Do not hesitate to use it.

Our Core Expectation

These projects should reflect your own interest in any domain of Virtual Reality of your choosing. Therefore, carefully select your topic, create a suitable virtual environment to showcase your implementations and underline the context in which the qualities of your contribution are highlighted. Beyond that, critically think and discuss advantages and disadvantages of your results and the involved concepts.

Most importantly, try to have fun and enjoy your journey into Virtual Reality.

Getting Started

For the final project, you are allowed to form new groups or stay within the one of your regular assignments completed in the lab class. You have several options for determining your final project topic. You may:

- Option 1: Propose your own project idea
- Option 2: Select from our list of pre-defined single-user VR topics
- Option 3: Select from our list of pre-defined multi-user VR topics
- Option 4 (new): User-Centered Design of a Multi-User VR Lecture System

For a detailed description of these options, please review the sections below.

Use any code framework from the previous assignments to develop your solutions. For Option 3 (and your own multi-user ideas) you can find another Unity project on Moodle, which you may use as a starting point for a multi-user interactive virtual environment.

Edit: Option 4 is an HCI focussed topic, which requires no implementation. If you choose this task, we therefore expect a thorough theoretical investigation, solid concept proposal and extensive design sketches in your presentation.

Option 1: Propose your own project idea

If you would like to propose your own project idea or if you choose topic *Build Your Own Social VR Experience* (see bottom of section *Option 3*), please complete the following questionnaire outlining your plan:

- Please provide a brief summary of your topic. *[1-3 sentences]*
- How many people are participating? *[no more than 4]*
- To which concepts presented in the lecture does your idea relate? *[List of Keywords]*
- Which features are you planning to design and/or implement that would address these concepts? *[5-10 sentences]*
- How are your planning to distribute work between the group members? *[1-2 sentences per group member]*
- Do you need additional hardware? If yes, what do you need? *[bulletpoints, if any]*
- Do you have any additional comments? *[as needed]*

Create a pdf document from the completed questionnaire and send an email to **sebastian.stickert@uni-weimar.de** and **ephraim.schott@uni-weimar.de** to get your topic approved. Please plan your project idea in a way that the total time to be spent on it does not exceed 45 working hours per person (1.5 ECTS).

Option 2: Select from our list of pre-defined single-user VR topics

The following list gives an overview of potential final project topics that you can choose from in the domain of single-user VR. Please note that each topic can only be completed by a single group. You can claim a topic in the corresponding Moodle activity.

Also note, there are different variations for the Photoportal topic (across single- and multi-user options). Since the core of each variation relies on the same basic implementation, only one of those tasks will be handed out to one group of up to 4 students.

[1 Student] iSith (Wyss et al. 2006)

Implement the two-handed iSith technique by Wyss et al. for distant object dragging. Extend your implementation with a way to also rotate the selected objects based on the two ray pointers. You might use the buttons on your controllers to switch between dragging and rotation.

Reference: Wyss, H. P., Blach, R., and Bues, M. (2006, March). iSith-Intersection-based spatial interaction for two hands. In 3D User Interfaces (3DUI'06) (pp. 59-61). IEEE.

[1 Student] Distant Object Manipulation (Bowman et al. 1997)

Implement the HOMER technique described by Bowman et al. including the two extensions described in Section 4. Please do also implement and compare the two presented techniques for bringing the objects close to the user. Finally, implement the Stretch GoGo technique and compare all of your implementations for distant object manipulation tasks.

Reference: Bowman, D. A., and Hodges, L. F. (1997). An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments. SI3D, 97, 35-38.

[2 Students] GulliVR (Krekhov et al. 2018)

Implement the GulliVR navigation technique described by Krekhov et al. with using *Aiming* to transition from giant mode to normal mode. The technique only allows transitions between two discrete heights for navigation. Find a suitable extension to GulliVR that allows the user to transition between different height levels. Compare your implementation of GulliVR to basic pointing-directed steering for long distance navigation.

Reference: Krekhov, A., Cmentowski, S., Emmerich, K., Masuch, M., and Krüger, J. (2018, October). GulliVR: A walking-oriented technique for navigation in virtual reality games based on virtual body resizing. In Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play (pp. 243-256). ACM.

[2 Students] River Analogy (Galyean 1995)

Implement a simple variant of the River Analogy technique by Galyean for navigating through immersive virtual environments. The user should be guided along a pre-defined path with a certain speed and should be able to slightly stray away from the path when giving inputs. At certain points along the path, vary the parameters of your implementation such that they are suitable for exploring the virtual environment. Find a suitable mechanism to let the user choose in which way they would like to continue traveling on a forked path.

Reference: Galyean, T. A. (1995, April). Guided navigation of virtual environments. In Proceedings of the 1995 symposium on Interactive 3D graphics (pp. 103-ff). ACM.

[2 Students] Redirected Walking (Razzaque et al. 2005)

Implement a redirected walking locomotion technique as described by Razzaque et al. to enhance the size of your workspace. As outlined in the paper, apply a rotation to the users movements to change their real world direction. Find suitable parameters to reduce the simulator sickness to a minimum.

Reference: Razzaque, S., Kohn, Z., Whitton, M. C. (2005). Redirected walking (pp. 4914-4914). Chapel Hill: University of North Carolina at Chapel Hill.

[2 Students] Physical Walking for Navigation (Williams et al. 2007)

Implement the Freeze-Backup and 2:1 Turn techniques by Williams et al. Decide on a suitable way to trigger the techniques during physical walking in the tracking space. The authors do not specify any visual feedback that tells the user what is happening and what they should do during the Freeze-Backup and 2:1 Turn phases. Design a suitable visual mediation to communicate this to the users.

Reference: Williams, B., Narasimham, G., Rump, B., McNamara, T. P., Carr, T. H., Rieser, J., and Bodenheimer, B. (2007, July). Exploring large virtual environments with an HMD when physical space is limited. In Proceedings of the 4th symposium on Applied perception in graphics and visualization (pp. 41-48). ACM.

[2 Students] Worlds in Miniature (Pausch et al. 1995)

Implement flying into hand-held world-in-miniatures (WIM) by Pausch et al. for navigation. To this end, allow the user to manipulate an avatar in the WIM and implement the transition described in the paper to make the user take the specified viewpoint. Apart from avatar dragging, implement an alternative way of specifying the intended position and orientation of the user.

Reference: Pausch, R. F., Burnette, T., Brockway, D., and Weiblen, M. E. (1995, September). Navigation and locomotion in virtual worlds via flight into hand-held miniatures. In Siggraph (Vol. 95, pp. 399-400).

[2 Students] PRISM (Frees et al. 2007)

Implement a dynamic object translation and rotation technique as described by Frees et al. to allow for a more accurate direct object manipulation.

Reference: Frees, S., Kessler, G. D., Kay, E. (2007). PRISM interaction for enhancing control in immersive virtual environments. ACM Transactions on Computer-Human Interaction (TOCHI), 14(1), 2-es.

[2-4 Students] Photoportals (Kunert et al. 2014) in Single-User VR

Implement a stereoscopic Photoportal. The portal view should act as a dynamic window from one location in your virtual scene to another. Therefore, the off-axis projection rendered into your portal texture should be calculated with respect to the user position towards the portal. Similarly, make sure your implementation is robust towards runtime transformations of the portal view (portal entrance), as well as the portal camera (portal exit). Explain the calculation of the projection matrices involved.

Review Lecture 13 (specifically slides 40-61) for a summary of the aforementioned concepts.

If done by 2 Student Group

Discuss how your implementation could be extended given one of the advanced concepts on Photoportals e.g. Transition into Portal (Navigation), Ray Interaction using Portal (Selection and Manipulation), Cube Portals (Advanced Interactions) or your own creative idea.

For larger groups

Extend your implementation given one of the advanced concepts on Photoportals discussed in the lecture e.g. hand-held portal camera with capture feature and gallery, transition into portal, object extraction, grabbable cube portals or your own creative idea.

Reference: Kunert, A., Kulik, A., Beck, S., and Froehlich, B. (2014, February). Photoportals: shared references in space and time. In Proceedings of the 17th ACM conference on Computer supported cooperative work and social computing (pp. 1388-1399).

Option 3: Select from our list of pre-defined multi-user VR topics

The following list gives an overview of potential final project topics that you can choose from in the domain of multi-user VR. Please note that each topic can only be completed by a single group. You can claim a topic in the corresponding Moodle activity.

Also note, there are different variations for the Photoportal topic (across single- and multi-user options). Since the core of each variation relies on the same basic implementation, only one of those tasks will be handed out to one group of up to 4 students.

[4 Students] Photoportals (Kunert et al. 2014) in Multi-User VR

Implement a stereoscopic Photoportal in a distributed multi-user virtual environment. The portal view should act as a dynamic window from one location in your virtual scene to another. Therefore, the off-axis projection rendered into your portal texture should be calculated with respect to the local user position towards the portal. Similarly, make sure your implementation is robust towards runtime transformations of the portal view (portal entrance), as well as the portal camera (portal exit). Explain the calculation of the projection matrices involved. Review Lecture 13 (specifically slides 40-61) for a summary of the aforementioned concepts.

Implement a simple hand-held portal camera placed in your multi-user scene. While it is not handled by anyone, a user can grab it and move the portal view (entrance) via direct manipulation. While it is grabbed, the interacting user should be able to translate the portal exit using joystick input (y-Input: translation along screen forward vector; x-Input: translation along screen right vector). Updates to the portal should be distributed across the network, to ensure a coherent workspace for all application clients.

Discuss how your implementation could be extended to allow for complimentary input using the portal camera.

Reference: Kunert, A., Kulik, A., Beck, S., and Froehlich, B. (2014, February). Photoportals: shared references in space and time. In Proceedings of the 17th ACM conference on Computer supported cooperative work and social computing (pp. 1388-1399).

[3-4 Students] Bent Pick Ray (Riege et al. 2005)

Implement the Bent Pick Ray technique by Riege et al. for two users in a multi user virtual environment. As outlined in the paper, apply the scaled-grab technique for object dragging and realize different weights for user inputs.

Reference: Riege, K., Holtkamper, T., Wesche, G., and Frohlich, B. (2006, March). The bent pick ray: An extended pointing technique for multi-user interaction. In 3D User Interfaces (3DUI'06) (pp. 62-65). IEEE.

[2 Students] Getting there together (Weissker et al. 2020)

Implement a Multi-Ray Jumping and Positioning technique in a distributed virtual environment as described by Weissker et al. with a second remote user as the passenger in the virtual environment. Think about how comprehensible group jumping and positioning could be realized for more than two users (without adding an individual target ray for each user) and demonstrate your implementation within a group of 5 users (you may add simulated users for this task). What are the advantages and disadvantages of group jumping as opposed to group steering?

Reference: Weissker, T., Bimberg, P., Froehlich, B. (2020). Getting There Together: Group Navigation in Distributed Virtual Environments. IEEE transactions on visualization and computer graphics, 26(5), 1860-1870.

[2-4 Students]* Build Your Own Social VR Experience

Use what you have learned about collaborative Virtual Reality and apply your knowledge to implement your own (small) social VR experience. Determine, investigate and present the context of your social VR experience. As an extension to the example codebase we supply, design, implement and discuss at least two features to enable (or enhance) multi-user interaction along your chosen context. Domains for your investigation can include, but are not limited to:

- shooter mechanics
- synchronized recording and playback of video sequences
- distributed selection techniques
- (temporary) group navigation techniques
- presentation tools
- ...

*This topic is open for individual exploration. Therefore, it can be selected by multiple groups.

Option 4: User-Centered Design of a Multi-User VR Lecture System [2-4 Students]

The covid-19 pandemic has lead to a remarkable transformation of education and the tools used in the day-to-day workflow to conduct teaching, learning and presentations. Several studies have dealt with the phenomenon of zoom-fatigue, which describes the exhaustion of using video communication tools. While there remain to be definitive answers to the exact cause of the effect (and how to solve it), we believe that Virtual Reality technology has the potential to overcome a variety of challenges involved with online teaching. To enhance social presence and awareness, participation, comprehensibility as well as overall enjoyment within our lecture offering, we are planning to build and evaluate a VR system which will host core parts of our remote teaching efforts.

As a task for your Final Project you should design a concept for a multi-user VR system for teaching and learning in Virtual Reality. The contextual focus of the system is conveying the concepts, methods and technology taught during our Virtual Reality lecture. To address this topic, you should propose an architecture and design concept, which could guide the development of such a system.

Your investigation should cover the following aspects:

1. *User-centered analysis of the problem space*: Initially, you should address the topic domain without any thoughts towards your proposal included. You may freely pull from any set of HCI methodologies to unfold and analyze the problem space. Brainstorming user stories and personas may be useful tools to organize and present your thoughts effectively. The following categories and questions may guide your initial investigation.
   a) **People**: What is the target audience of the VR lecture? What are the individual needs, roles and various relationships towards each other?
   b) **Actions**: How do participants interact and exchange information (individually and collectively)? How is communication and collaboration structured? What

kind of tasks exist to encourage learning and which feedback cycles exist to resolve issues? What is the conceptual flow of participation and social interaction during the lecture and exercise?

   c) **Context**: How is the content and workflow structured within the lecture? What are the core values and limiting factors within the given context? How do the actions of participants depend upon each other? What is focus of communication and social interaction?

   d) **Technology**: What hardware and software is currently being used to aid the context? In which ways is this technology supportive and/or restrictive towards individual and collective requirements within the context?

2. *Related Work research:* Self-sufficiently identify and discuss relevant academic work and existing applications in the field of presentation systems and learning in VR. How does the identified work apply to the analyzed problem space? What are the main takeaways to guide your further investigations? Which open questions do those contributions lead?
3. *Research Questions:* Come up with representative research questions, which are derived from your initial investigation of the problem space. They should guide your continued efforts and your proposed concept should be tailored towards answering them.
4. *Architecture Concept Proposal:* You are free to propose any practical concept along the points mentioned above. Your proposal can aim at an overall architecture for conducting the lecture, or focus on a set of in-depth specific features. In any case, state a clear overall vision of your proposal. Highlight aspects of the knowledge you have gained throughout the Virtual Reality lecture that lay at the core of your contribution and why you expect them to enhance the overall teaching and/or learning experience. Design a clear specification of (some) representative interaction methodologies, the structure of the virtual environment and VR hardware being used in your system architecture. To visualize interaction sequences, the layout of your scene and users within it; make extensive use of paper prototypes and design sketches. These are vital to a comprehensible presentation of your concept proposal and therefore mandatory for your task. Your presentation should be polished enough, so that a VR engineer can begin a prototypical implementation without any major questions.
5. *Study Design:* Propose a studies design to evaluate your system with respect to the Research Questions you have identified.