Woodwork with cobots

- a concept study visualized as a VR-experience

Bachelor Thesis

Digital Media

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Abstract

This thesis addresses the integration of collaborative robots (cobots) into the craft industry, specifically within the woodworking contexts. The primary objective is to develop and evaluate a conceptual framework for a virtual reality (VR) application designed to simulate interactions with cobots during woodworking tasks. The application allows users to engage with cobots in cushioning a chair. This interaction involves following instructional prompts, engaging with the cobot sequentially, and integrating its assistance to complete the task. Evaluation of the proposed concept focuses on technical functionality and user experience, utilizing the System Usability Scale (SUS) to assess the application's usability. Results show that the VR application is technically working and has good usability according to the SUS. However, further evaluation is needed to assess the practical use of the proposed concept, as insights from industry professionals are limited. Thus, additional research and engagement with stakeholders are needed to determine the ultimate potential of integrating cobots into woodworking practices.

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1 Introduction

1.1 Motivation

In our rapidly evolving world, many individuals feel a sense of being left behind. The pace of technological advancement is unparalleled, and perceptions of robotics and AI are often shaped by media portrayals, such as television shows or video games. However, these representations may not always align with the current state of technology; they can either seem distant or surprisingly close to reality. This disparity becomes particularly pronounced in traditional job settings, where established practices have endured for an extended period.

Consequently, there's a growing apprehension surrounding change and uncertainty (Seng, 2018; McClure, 2017).

To address these concerns, developing applications that provide information and serve as educational tools are important. These applications aim to impart knowledge about new concepts and evolving systems, which are becoming increasingly relevant sooner than anticipated.

Combined with the interest of developing games and VR applications and the already mentioned social aspects this work aims to enhance the knowledge about making applications for people, create interesting interactions and projects.

1.2 Aim for this thesis

The aim for this thesis is to develop an application that offers insights into the future role of cobots within the craft industry, particularly in woodworking environments. Further, give an outline of a possible workflow, by creating a workplace and interactions that feel approximately realistic.

Also improve understanding of how humans interact with cobots, as well as delivering a high-quality application that users can test and provide feedback on.

After developing the application, conduct a survey to evaluate the application, and an interview with an industry professional to evaluate the proximity to reality.

2 Related Work

2.1 KoRA – EXPERIENCE collaborative robotics

"Preparing for the working world of tomorrow in virtual learning worlds." (KoRA, 2024.).

KoRA is a project in which the KoRA-MR learning software has been developed. It is designed to teach and further educate humans on interactions with cobots, by creating digital transfers of real-world scenarios.

2.2 Human-Centered Design of a Collaborative Robotic System for the Shoe-Polishing Process

The paper Human-Centered Design of a Collaborative Robotic System for the Shoe-Polishing Process (Chiriatti et al., 2022) discusses the development of a robotic system for shoe polishing. The system aims to automate the process while maintaining high product quality and reducing manual labor. The use of collaborative robots allows for a safer and more ergonomic workspace. This is particularly beneficial for small and medium-sized enterprises in the fashion industry. The paper by Chiriatti et al. also discusses the impact of process parameters and design solutions, providing insights for future developments. The human-robot collaboration aspect is emphasized, especially in industries where manual work is crucial, like the footwear industry.

2.3 KIWI - Further education scenarios in mVR

"Artificial intelligence for tailored training and continuing education to strengthen employability in the context of progressive digital penetration of production in the context of Industry 4.0." (KIWI, 2024).

The KIWI project focuses on developing an application for production employees to facilitate easy access to training and further education opportunities using artificial intelligence. The rapidly changing nature of production due to digitization and automation underscores the need for continuous skill development and adaptation. Additionally, the project integrates mobile Virtual Reality as a learning tool. Collaborative robotics is used as a case study, highlighting its significance in the digitalization process and the demand for targeted training opportunities.

3 Foundation / Setup

3.1 KIWI - Cobots

This work uses features developed in the Unreal Engine (UE) project based on KIWIs UE project such as the character, cobot, interactions, and the tutorial- level.

A cobot is a collaborative robot that is designed to work together with a human even in close space and without a cage or other restrictions in direct human-robot interaction (Guertler et al., 2023; Van, 1996).

3.2 Character

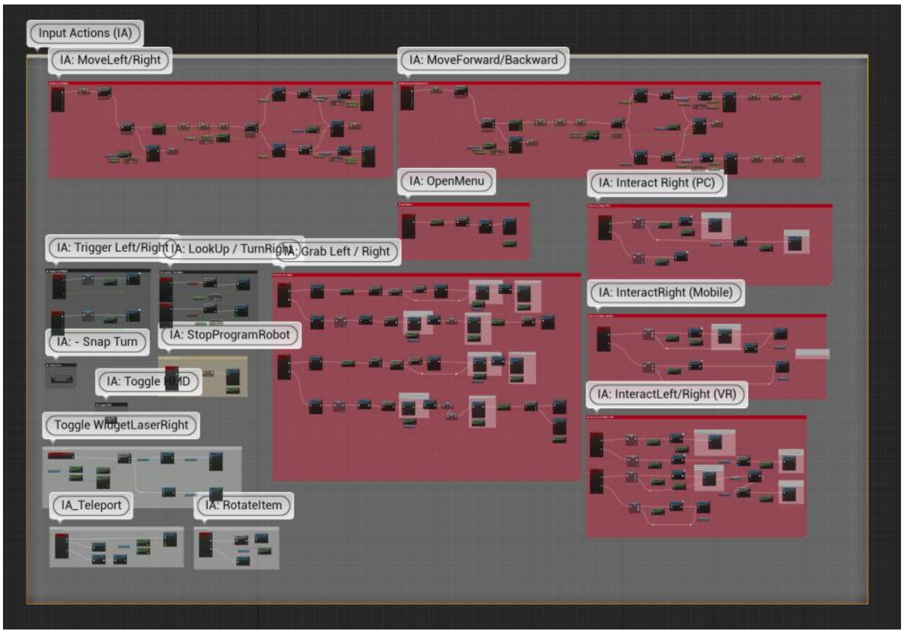
The blueprint class "BP_VRPawn" is an Unreal Engines character[1] blueprint that contains a CharacterMovementComponent, a CapsuleComponent, and a SkeletalMeshComponent. It is the basis of many applications, especially games made with the UE. Inside the KIWI project it got implemented further to fit special needs, such as working in VR and non-VR and even for mobile usage. Most functionality was untouched for this work and remained as it is throughout the implementation.

The character handles all movement input actions (see Figure 1) such as move forward, move right, teleport, etc.... Everything the user sees is through the camera of the character that is positioned from a first-person perspective.

[1] (https://dev.epicgames.com/documentation/en-us/unreal-engine/characters-in-unreal-engine)

Figure 1

The character blueprint



3.3 Cobot

The cobot "BP_Robot" used is based on the UR5 (Figure 2) from Universal Robots (https://www.universal-robots.com/products/ur5-robot/). It contains many different features such as moving and rotating along a given path, creating the path, and using tools like a gripper, and a tablet to interact with. The movement of the end effector[2] was realized as follows: The user grabs the effector and moves it to its desired location, by pressing the interact- button it opens a menu to select the desired action for this location such as e.g. grab, wait, drop, and ending the programming by pressing the end- button. With the end effector programmed the cobot moves his joints according to the position based on the inverse kinematics (IK).

[2] The end effector (also known as end-of-arm tooling) sits at the end of the robot arm and moves only when a human operator activates it through the associated software (https://onrobot.com/de/node/2077).

The IK gets calculated with a Plugin from KIWI which takes in the location and rotation from the end effector and returns the angle for each 6 joints. These rotations are applied to the skeletal mesh of the cobot.
The locations of a path (ST_ProgrammedLocations[3]) can be saved for future interactions where the user should not program the cobot on his own but use an already implemented pathing. This is done via the save and load functions from the “SaveGame”- blueprint (Save Game, 2024).

Figure 2

UR5- cobot inside Unreal Engine

3.4 Tutorial

The tutorial explains and teaches all major concepts and interactions inside the application such as moving, starting the cobot and grabbing items. It features rooms and instructions which take between 5 to 10 minutes to pass for a non- VR- experienced user.
Halfway through the tutorial the path’s splitting away into a room teaching how to program a cobot and a room explaining how to screw screws into a block with a screwdriver. The second way leads to a teleporter which teleports to this woodworking with cobots scenario. So, for this work the first path was locked and everyone had no choice but to enter the woodwork scenario, which is part of this thesis.

[3] The programmed locations structure is a struct variable (Blueprint Struct Variables in Unreal Engine, 2024) that contains multiple information such as the location and rotation.

3.5 OpenXR

"OpenXR is a royalty-free, open standard that provides a common set of APIs for developing XR applications that run across a wide range of AR and VR devices. This reduces the time and cost required for developers to adapt solutions to individual XR platforms while also creating a larger market of easily supported applications for device manufacturers that adopt OpenXR." *(OpenXR, 2016)*.

To run the application for the Oculus Quest2 (Quest2) on any computer the Oculus Quest Link application is needed which acts as a OpenXR-runtime and therefore enables the communication between the head-mounted display (HMD) and the UE-application. OpenXR made the process of connecting a Quest2 HMD to the application quite easy and supports many different HMDs as well.

3.6 Global Event System

One important aspect of the infrastructure of the UE project is the Global Even System (GES).

The GES is a plugin for the engine that allows a faster and easier communication structure inside UE's blueprints (https://github.com/getnamo/GlobalEventSystem-Unreal).

4 Concept

4.1 Idea

The idea is to create a woodworking scenario in VR in which the user experiences collaboration with a cobot and fulfills a job as well as incorporate real-world usage of cobots in a small or medium-sized enterprises (SMEs).

The user's task is to cushion a chair by sanding the seat, then applying glue and finally putting a cushion on it. Steps related to the production process are implemented in a simplified way to set the focus on working with the cobot itself. Also shown tools and ways to work with a cobot are included that are not often seen associated with cobots like the UR5.

4.2 VR

To enhance immersion and achieve a potentially more realistic experience, VR application was selected as the medium. This choice brings the dimensions of the room and the interaction with the cobot closer to a real-world scenario.

4.3 Integration

Most SMEs aren't interested in collaborative robotics due to a seemingly high cost which could cause the absence of knowledge about possible integrations of cobots (Einertshofer, 2018).

This problem could be tackled by creating more representations of cobots working in direct human-robot interactions in small spaces that look like their own workshop.

In order to expand the typical practical application of cobots with tasks such as transferring objects with grippers, it is essential to introduce new tools and explore different scenarios.

One interesting example of a tool for cobots, already utilized by a SME, is the sander developed by OnRobot (Awesome Technologies, 2021; Sander Tool for Collaborative Robots, 2024). It is used e.g. to eliminate the exhausting task of sanding a piece of wood and is one of the two integrated cobot tools in this work which will be explained further in chapter 5.2 (Cobot tools).

Another tool with a real use case is a glue gun or glue dispenser used in a small company (Präzises Verkleben Dank Cobots, 2024). It places glue precisely onto objects which enhances the enterprise's product quality and reduces waste.

The “Human-Centered Design of a Collaborative Robotic System for the Shoe-Polishing Process” (Chiriatti et al., 2022) mentioned before is an example of what a successful realization of this idea looks like.
The last integration needed to be mentioned is the automatic changing of tools the cobot can use.
In many use cases cobots have one distinct end effector which is mounted and remains as it is. What happens when the cobot could change the tool all by itself? The possibility of this idea is demonstrated by TripleA robotics (TripleA robotics, 2021).
This concept is explained further in chapter 5 (Implementation).

4.4 Scenario

4.4.1 Setting

The scene is set in a small workshop with shelves holding tools and materials as seen in Figure 3. It is like a typical workspace you would find in today's craft industry, with workstations and resembling desks. Everything is in close range and accessible without machinery.

Figure 3

Woodwork- level overview

4.4.2 Loop

Typical for any kind of game development is a loop (game loop) that describes the interactions a user does and how it is processed until the application ends (Emberwit, 2016).

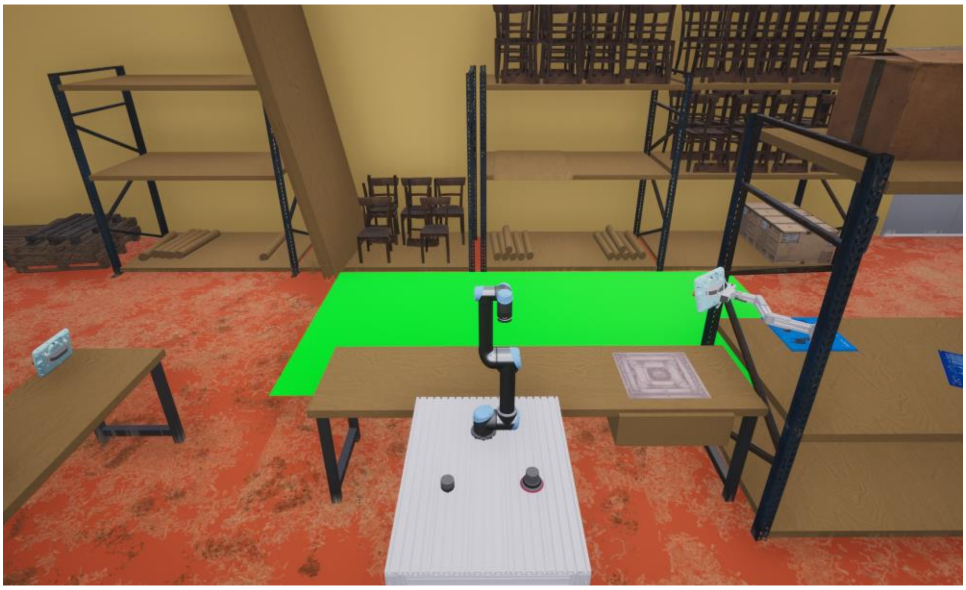
Even though this application is not a game, many features are similar to game features and the included gamified interactions enhance this parallelism as well.

The following describes the general loop:

After the introduction to VR in the tutorial, the user spawns in a workshop designed to enhance working with the cobot but maintaining characteristics of a small enterprise (Figure 3, 4).

Figure 4

Woodwork- Level working area



The user has to cooperate with the cobot to process the given resources (chair and cushion) into a new product (chair with a cushion) by placing the resources on the table, starting the cobot and combining the pieces afterwards. For the most part the user moves inside the green marked zone visible in Figure 4.

To get the cooperation working correctly, the user should follow instructions (see chapter 4.4.3) that add guidance to successfully fulfill the job.

4.4.3 Instructions

This is the list of instructions used in the scenario:

1. Platzieren Sie eine Blaupause auf dem Tisch um zu beginnen.
2. Greifen Sie den Stuhl, der hinter Ihnen steht und platzieren Sie ihn auf dem Tisch.
3. Nun berühren Sie das Tablet, um dem Cobot mitzuteilen, dass dieser starten kann.
4. Warten Sie bis der Cobot in die Warte-Position übergeht. Dies geschieht, nachdem dieser die Sitzfläche aufgeraut hat und anschließend den Kleber aufgetragen hat.
5. Platzieren Sie das Polster auf dem Stuhl.
6. Greifen Sie den Stuhl und transportieren Sie ihn zu den freien Paletten neben dem 2. Cobot.

Writing it in German aimed to help minimize the chances of users not understanding the instructions.

5 Implementation

The implementation was done with the Unreal Engine (UE) version 5.2.1, Blender and Audacity. Inside UE, blueprints were used to create and edit assets for the most part of the implementation.

Some important naming prefixes for assets are to mention which for the most part align with the UE naming conventions[4].

These are:

BP: Blueprint, DT: Data Table, ST: Structure, E: Enum, SM: Static Mesh

5.1 Editing existing features

The KIWI project already had many implementations and features which had limited capability to incorporate some of the features that needed to be implemented for this project.

The first asset is the "ST_ProgrammedLocations" for the cobot mentioned previously. To add different tools to the cobot, the ST had to be changed from having just the input grab/drop (true/ false to an Enum "E_LocationActions" which contains more constants than grab and drop, e.g. "grabToolHead" to grab a new tool, "dropToolHead" to drop an attached tool, "sander on" to start a sander, "sander off" to stop a sander.

Next is the Robot itself that had just a static gripper attached to the skeletal mesh but needed a changing mechanism for different tools to attach to. To achieve such a possibility a new class for the gripper and other tools had to be implemented, the "BP_HeadTool" which consists of a static mesh that gets overwritten by the child, as well as some simple functions such as "GetType": returns the type (E_HeadToolType, an Enum containing all different tools available) of the tool, "GetActionLocation": returns the location of the endpoint of the tool.

[4] (https://dev.epicgames.com/documentation/en-us/unreal-engine/recommended-asset-naming-conventions-in-unreal-engine-projects?application_version=5.2).

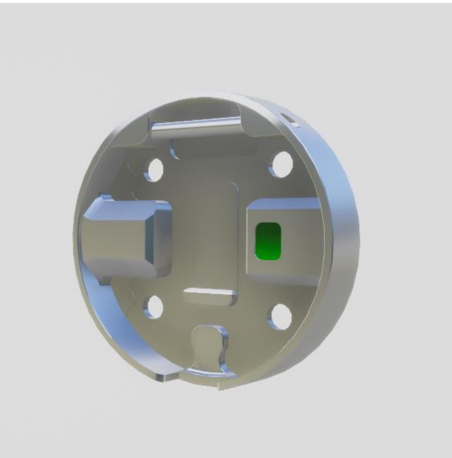
In addition to the tools, the “SM_Onrobot_QuickChange” (QC) became the new asset that is attached to the endpoint of the cobot and serves as the end effector as long as no tool is attached (Figure 5, 6). The QC is a real product from OnRobot[5] which had already been in the project and serves as an important connection to the real-world for the implementation of different tools (Robot Quick Changer End of Arm Tooling, 2024).

Figure 5

Quick Changer inside Unreal Engine, front

Figure 6

Quick Changer inside Unreal Engine, back



[5] Onrobot is a shop for all kinds of products related to cobots. (*One Stop Shop for Collaborative Robot Applications*, n.d.)

5.2 Cobot tools

The QC integration is an important foundation of the new tool system concepted and implemented. Besides the existing gripper that can grab and drop items, a sander that is able to sand surfaces and a glue gun that can apply glue on a spot was implemented. All tools share the same superclass “BP_HeadTool” mentioned previously and most core functionalities. They differ in size and the event that gets fired, the so called “Event_LocationAction” (LA).

The sander “BP_Sander” is loosely modeled and designed after the sander from OnRobot (Sander Tool for Collaborative Robots, 2024; see Figure 7, 8). Its look is quite abstract but serves the setting.
The LA ”SanderOn” starts the sander and plays a sound file that can be heard until it is turned off again.
To stop the sander the LA ”SanderOff” needs to be called by the cobot through the interface.

Figure 7

Sander inside Unreal engine

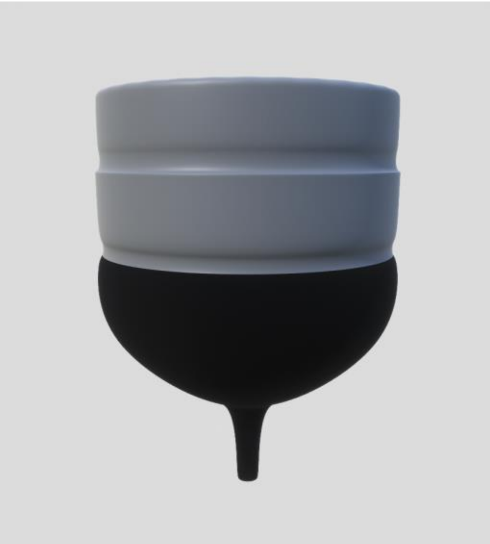
Figure 8

Cobot with Sander inside Unreal engine

The glue gun "BP_GlueGun" in contrast to the sander is not a real product but inspired by the tools used in two different companies (*Präzises Verkleben Dank Cobots*, 2024; Hohe Mitarbeiterzufriedenheit Mit Cobots, 2024). It functions like a typical glue applicator spreading glue via a little tube. To make it simple and easy to work with, the hoses to refill the tube and other necessary things got abstracted as seen in Figure 9. The two main functionalities are opening the tube to spill glue and closing the tube via the LA "UseGlue" and "StopGlue".

Figure 9

Glue Gun inside Unreal Engine



5.3 Items

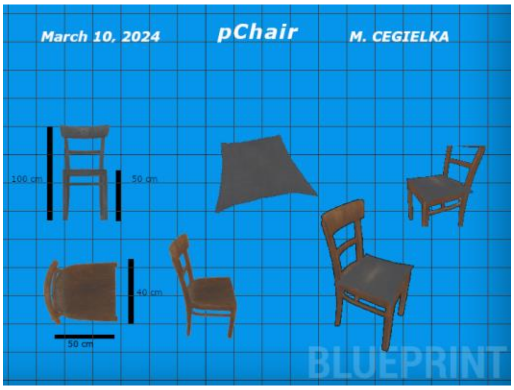
In addition to the tools implemented in the last chapter, other objects were implemented that will be referred to as items. In contrast to the tools, which could only be used by the cobot, items can be used by the cobot and the user himself. These items and their setup will be described in the following section.

5.3.1 Blueprint

The "BP_BlueprintItem" (BI) is an item (Figure 10) that functions as the starting point for this scenario. Its core function is the "Event_SetupItems" that occurs when it is placed on the desired place (the scanner) on the work desk. The texture of the BI has no actual real-world references and purely serves as a simple illustration of a blueprint.

Figure 10

BP_BlueprintItem inside Scenario



First of all, a list of resources needs to be given to the BI to set up all resources for the scenario. This happens on construction of the BI via a data table of all constructions "DT_WoodWorkConstructions" seen in Figure 11.

The "Event_SetupItems" first checks if the given Map of "BP_ResourceItem"s is not empty, then iterates over every item inside it. The number linked to the item determines the number of resources spawned. The event is shown in Figure 12.

With different BIs, different constructions can be realized by adding new constructions to the "DT_WoodWorkConstructions" and linking them with a BI.

Figure 11

DT_WoodWorkConstructions inside Unreal Engine

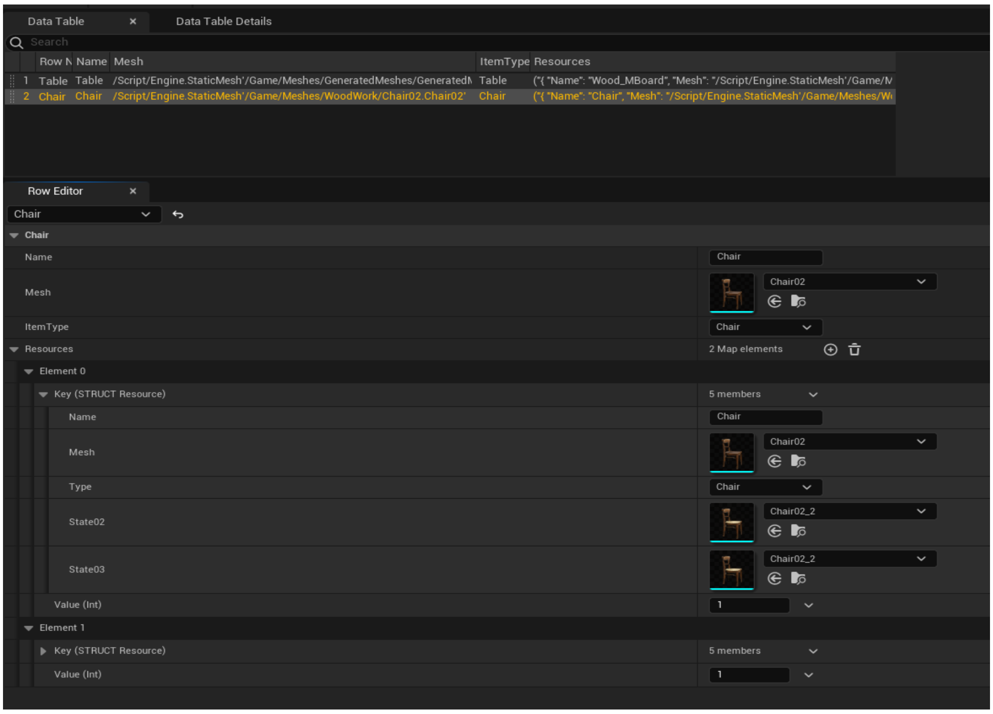
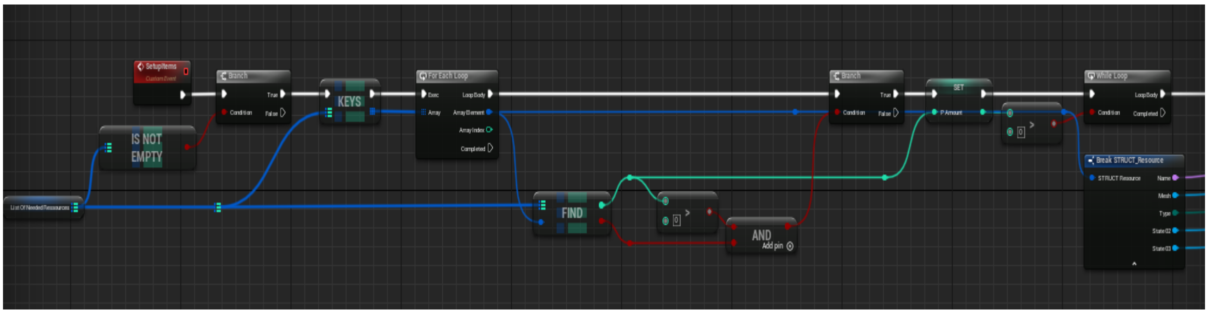


Figure 12

Event_SetupItems inside BP_BlueprintItem



5.3.2 Resource

A resource “BP_ResourceItem” is one of the items that a construction or product needs in order to be made. It can be processed with tools from the cobot or the user itself.

The two resources used in this scenario are a chair (Figure 13) and a cushion (Figure 14).

Figure 13

Chair inside Unreal Engine

Figure 14

Cushion inside Unreal Engine

These meshes got used from Unreal Engine's Quixel Bridge library[6].

5.3.3 Construction

As already mentioned in the last section, the construction is the product of a series of modifications to a resource.

In this scenario it is a cushioned chair or precisely a polished chair with a cushion glued on (Figure 15).

[6] (https://www.unrealengine.com/en-US/bridge)

Figure 15

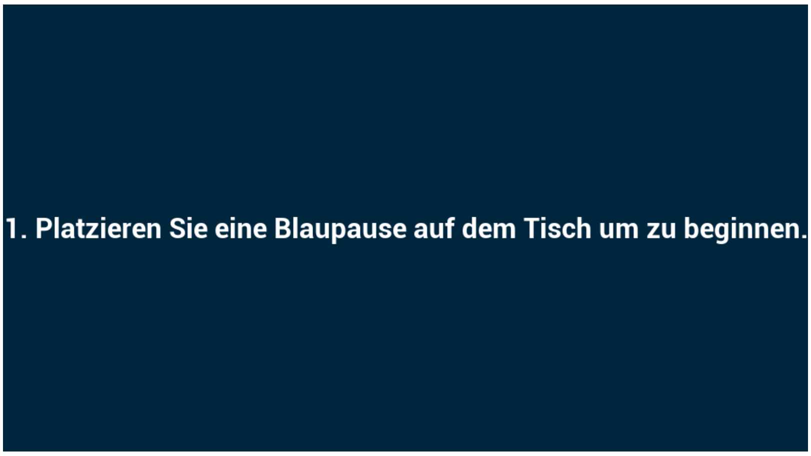
Chair with cushion glued on inside Unreal Engine

5.4 Computer & Instructions

The computer “BP_Computer” turned out to become more like an instructor than an actual computer. It is implemented to contain the widget “W_WoodWork_Screen” seen in Figure 16, which acts as a display for all the instructions of this scenario. To change the current visible instruction, the event “SetInstructionText” needs to be called with the instruction number to display via a message through the Global Event System (see chapter 3.6).

Figure 16

Display showing first instruction inside Scenario



5.5 Leveldesign & Modeling

Finally, everything had to be incorporated into one level.

The level "L_WoodWork" seen in Figure 17 consists of previously mentioned actors and some static meshes to enhance the setting and immersion as well as lighting and volumes. It combines the mentioned concepts and implementations and creates a coherent experience for the user.

Figure 17

Woodwork- level overview working area

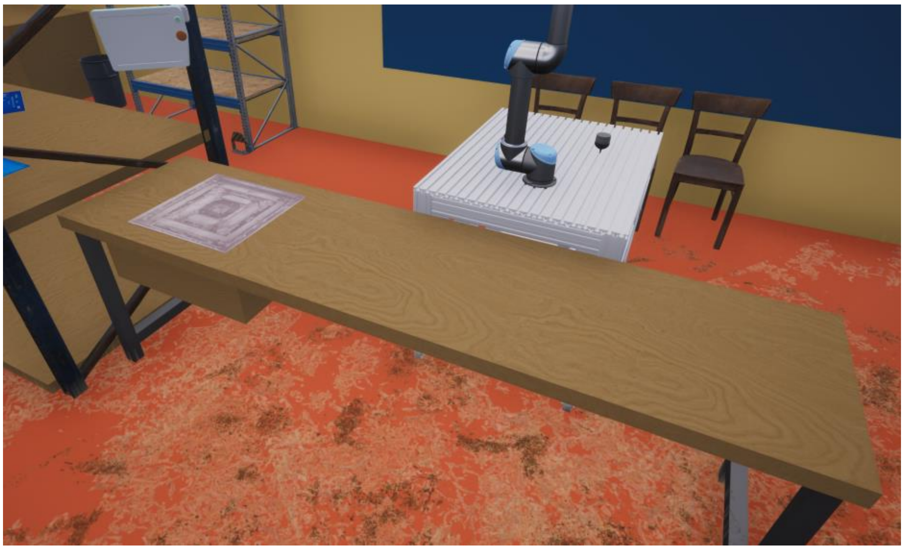
5.5.1 Modeling Tool

One of the first things to do in order to get a feeling of space and dimensions is to create a very simple and abstract version of the level with placeholders. Placeholders and simple objects are very easy to create inside UEs editor with the modeling mode. This mode can be accessed via activation of the plugin "Modeling Tools Editor Mode" (*Modeling Mode Settings in the Unreal Engine Project Settings*, 2024). Thus, simple meshes like the walls, the floor and some of the shelves could be modeled.

Even for the work desk and its legs it got utilized visible in Figure 18.

Figure 18

Workdesk inside Scenario



6 Evaluation

To evaluate the concept two separate parts should be considered. First comes the functionality & usability, followed by the content. If the first part is not provided many aspects of the content could be negatively affected.

Therefore, a user study was conducted to ensure the technical functionality.

6.1 Pilot study

The pilot study was undertaken at a conference in Bonn[7] where KIWI conducted a general testing of their software. So, an opportunity to test an early version of the software was given.

It featured a small number of people taking part in the questionnaire (3), but more people tested the actual status of the application and helped to find inconveniences and problems that could be reduced or eliminated soon after.

One rather big problem occurred and could be fixed within this testing which will be described in the following paragraph.

In order to test an application made with the Unreal Engine a compiled version or executable (.exe) is desired. With that, some errors can occur that might not while testing inside the editor of UE.

The problem that occurred was within the locations of the two resources (chair and cushion) which spawned on exchanged locations. This appeared exclusively in the executable version and not in the editor version which resulted in the chair being stuck inside a shelf and the cushion flying in midair.

The actual bug could not be fixed itself but the new way of setting the locations of the resources created a workaround and made the system at this point deterministic and not seemingly random.

In addition to that some small changes like removing the possibility to interact with the second cobot helped improve the scenario for the future user.

[7]The conference in Bonn was within the "INVITE"- competition held by the Bundesinstitut für Berufsbildung (BIBB) on March 10-13, 2024 (*BIBB - Innovationswettbewerb INVITE*, 2024).

6.2 User study

A survey was conducted from March, 2024-April, 2024, including 14 People at the age from 18 to 34. Out of 14 participants 12 answered. The others have answered a given questionnaire including the System Usability Scale (Brooke, 1996).

6.2.1 Procedure

Each participant was given an HMD (Oculus Quest 2) linked to a laptop running the Meta Quest Link application and the actual application containing the scenario.

Everyone got introduced to the controls for the movement by a step-by-step detailed explanation personally. (move-forward, teleporting and turning)

After this rather guided start to ensure everybody can move on their own, no more help was given outside the application.

The participants now pass the tutorial in which every necessary control and feature needed gets explained.

Now the actual scenario starts with the given instructions on the display.

After completing the scenario everyone scanned a QR Code linking to the questionnaire which got completed.

6.3 Interview

With the functionality and usability tested an interview with an industry expert followed the user study.

The interview should give insights concerning the content and its real-world relation.

One trained carpenter was interviewed, other requests got ignored and remained unanswered.

The interview took more or less 15 minutes and focused on the questions concerning the realism of the scenario and the problems it contains. For a full transcript of the interview see below (see appendix 1).

6.4 Results

Although 12 participants do not allow an in-depth analysis, but could give a good impression and tendencies, especially in the case when everyone answered the same.

6.4.1 SUS

It is common practice to assume that a SUS-score > 68 results in a software suitable to use.
The user study resulted in an SUS-score of 86.67 which concludes a good to great usability of the application, as well as a polished product without noteworthy errors or problems.

The least agreed on statement was (1): "I think I will use this VR application more often" and the most agreed on one was that they disagree with (10): "I had to learn a lot beforehand to use this VR application".
Table 1 shows the average answer given for each question on a scale from 0 (do not agree) to 4 (totally agree). For a full list of all questions and answers per participant, see Appendix 2.

Table 1

Average answer per Question

Question	1	2	3	4	5	6	7	8	9	10
Answer	2,25	3,8	3,6	3,5	3,7	3,7	3,2	3,7	3,2	3,9

6.4.2 General questions

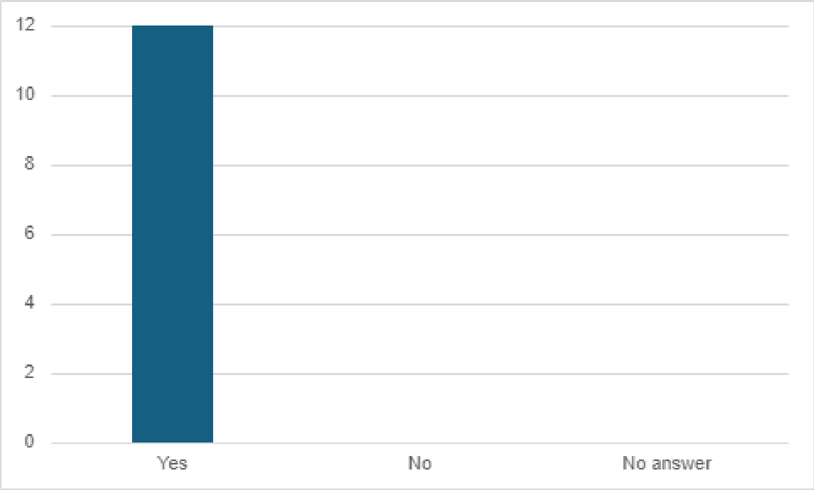
In addition to the SUS questionnaire the following questions were asked which are evaluated in Figure 19-21:

- Question W1: "*Konnten Sie das WoodWork-Level komplett durchspielen?"*
- Question A2: *"Wie alt sind Sie?"*
- Question A3: "Haben Sie bereits im Vorfeld eine Vorstellung von kollaborativen Robotern gehabt?"

Figure 19 shows that everybody could successfully complete the scenario.

Figure 19

Answers to Question W1: "Konnten Sie das WoodWork-Level komplett durchspielen?"



The next Figure (20) displays the age of all participants. Clearly an underrepresentation of older people is seen for this survey which could indicate a product that needs to be tested with people above 34 to verify the good usability across further age groups.

Figure 20

Answers to Question A2: "Wie alt sind Sie?"

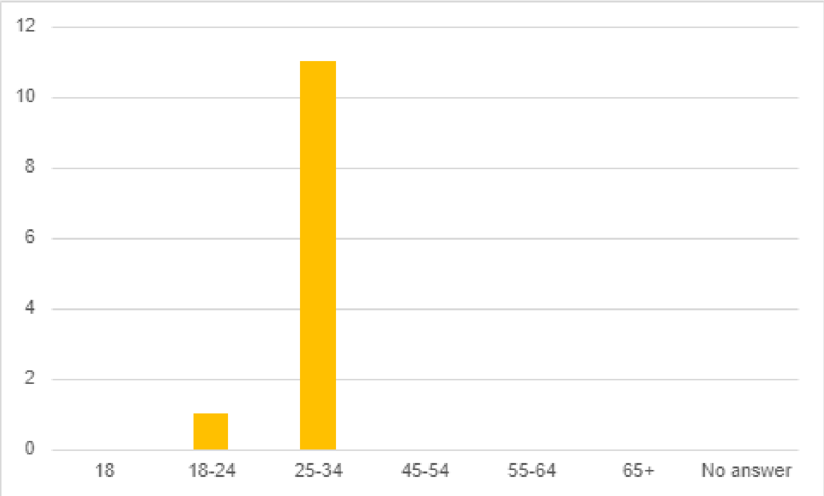
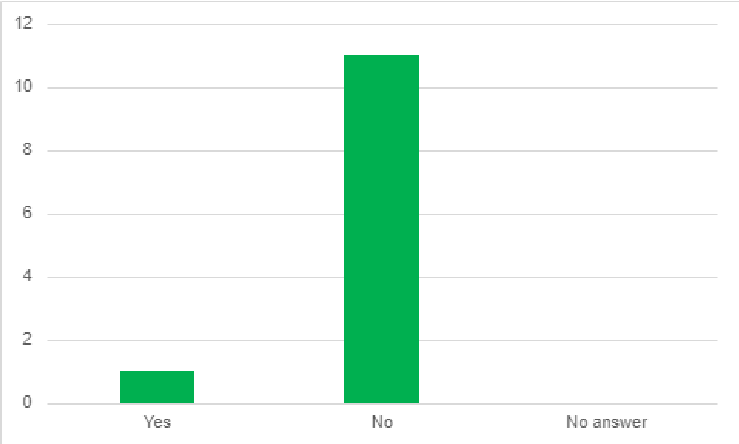


Figure 21 on the other hand indicates that this application requires no knowledge of cobots beforehand. This in addition to the 100% completion rate of the scenario seen in Figure 19, could result in a good tutorial that explains interactions with cobots successfully as well as a clear and understandable set of instructions.

Figure 21

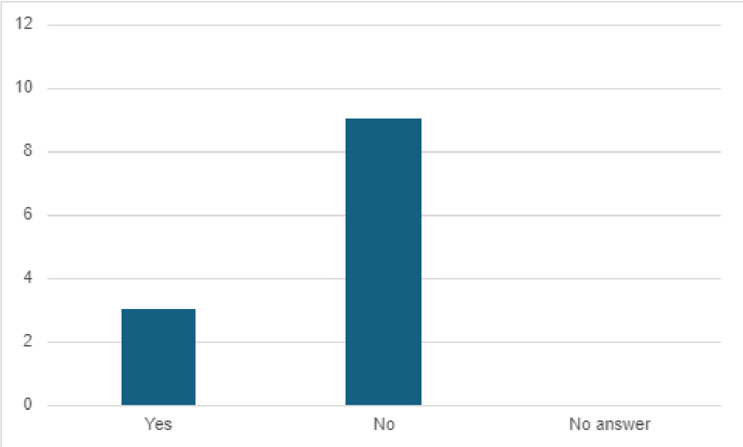
Answers to Question A3: "Haben Sie bereits im Vorfeld eine Vorstellung von kollaborativen Robotern gehabt?"



To give a complete overview of the participants Figure 22 needs to be taken into account. That presents if a participant is already experienced in using VR applications. 9 out of 12 (75%) already experienced a VR application before. Which can together with the high SUS- score lead to the assumption that experienced users have less issues with such applications and therefor have less usability related problems or the opposite that those participants better know what is "good" and "bad" by comparison.

Figure 22

Answers to Question A5: "War dies Ihre erste Virtual Reality- Erfahrung"



6.4.3 Interview questions

The first problem that was linked to integrating cobots into real-world practices was the seemingly high cost: *"Das Invest eventuell. Ich weiß nicht, was ein Roboterarm kostet."* (appendix 1, Wunderle, p2, l4). This linking aligns with the concerns of the SMEs mentioned before in chapter 4.3 (Einertshofer, 2018). From this we can conclude that the knowledge about cobots and probably robots in general is not sufficient enough for industry professionals to be interested in cobots to work with. More applications of cobots and their possible integration need to be done.

The interview reveals that the major missing integration is a mechanism to absorb upcoming dusk and particles: *"Das ist eigentlich das, was fehlt, wenn man ganz ehrlich ist. ... Aber im Endeffekt muss der Bereich, der geschliffen wird, auf jeden Fall abgesaugt werden."* (appendix 1, Wunderle, p4, l3). This could lead to health problems if the resource used consists of a dangerous material such as e.g. asbestos. A proficient solution needs to be developed to tackle this problem.

Overall, the scenario felt approximately real with many positive estimations towards integrating cobots into the craft industry in topics such as precision, quality in general and safety (appendix 1).

7 Conclusion & Outlook

This thesis aimed to develop and evaluate a concept that offers insights into the future role of cobots within the craft industry by creating a workplace and interactions that feel approximately realistic, the evaluation has shown that it is indeed approximately realistic according to the interview (see appendix 1). However, the shortage of diversified sources diminishes the significance.

Nonetheless the evaluation has shown that the application was well-received and functions with good usability. This was accomplished by a lot of testing and iterating over the application.

The pilot study helped notably to figure out errors and problems and fixing them resulted in a good application.

To aim for collaboration with industry professionals to craft a more realistic work environment involves replicating existing workflows and tasks with attention to detail. This can result in an authentic portrayal of the work setting and its outcome can be important to enhance the quality of the product. Not just to obtain insights and receive experience-based knowledge but for evaluation and analysis as well. It can create a better and more applicable product.

In this thesis a prototype was created that evolved into a scenario that functions as a reference for future discussions about how to integrate cobots into craft jobs. The most important aspects for a discussion are cobot tools, integrations and interactions with the cobot.

Future studies can build on this concept and dive into explicit realistic translations of real-world scenarios or change the setting completely by switching the domain.

In the end it is to say that VR- experiences are a great way to demonstrate concepts and visions in terms of delivering something a user can understand and interact with. It helped to improve the understanding of how humans interact with cobots and applications.

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Appendix

1. Transcript: transcript_interview01_27.0.2024.pdf
2. Survey: survey_results.pdf