**Transcript Video – English version**

So, as you can see, I'm currently at the collaboration lab of the IMI, but still, my colleagues on the other end of the corridor are nothing but a click of the mouse away from me.

Hi Julian.

Hi Carl.

How are you?

I'm good, wanna go?

Well, let's go for a walk, shall we?

*Roboter fährt auf dem Flur entlang*

*Beginn aufbauende epische Musik (SkyWorld von Two Steps From Hell)*

*fahrender Roboter wird in Videos gezeigt, dazwischen werden folgende Texte eingeblendet*

Move anywhere you want.

Steer with absolute precision.

Developed and tested by our expert Engineers.

To leave all our customers satisfied ….

… wherever they are!

Coming soon

*Ende Musik*

**Folie „Final Results — VR Practical Course — WS21/22"**

Hello and welcome, everybody! If you are curious about the prototype you just saw in the footage, look now further, as this video showcases the results of the Virtual Reality Practical Course held in the winter semester of 2021/22 here at the Institute for Information Management in Engineering at KIT.

**Folie „Motivation — Telepresence Robots"**

First of all, what is a telepresence robot, and why is it useful?

Well, it is basically a system just like the one we presented in the video, that features a screen and audio system for telecommunications but can also move around via remote control by the user, for example, via Wi-Fi.

Telepresence robots excel at creating a better social environment than regular video calls. As work colleagues who are not present in a certain location can simply login to the robot and move around in the same workspace as those who are. By doing so, they can also help cut traveling costs and increase the availability of a company's human resources, as it allows employees to be virtually in two places at once.

On the downside, most of the commercially available telepresence robots are rather expensive, lying within a price range of several thousand euros, such as the Ohmni model that is also present at the IMI.

**Folie „Our Solution: Selfmade Robot!"**

Our solution to this problem was to create a DIY version of a telepresence robot that stands out through its low costs, as all the necessary components to build it can be purchased online or at a hardware store in your area. Which also enables families and educational institutions with lower budgets to build their own.

A shopping list with our recommendations for buying many of the parts as cheaply as possible is part of the documentation we submitted to the institute.

When buying everything required to assemble our hardware, it is possible to stay below a threshold of 200 euros. The only thing not included in this estimation is the tablet PC, as the system is compatible with a lot of models, and it is up to the user how much money to spend here.

A lot of perfectly sufficient Android tablets are available at a price range of less than 200 euros as well, which still makes our entire system much cheaper than any of the commercial models. Alternatively, users could also choose to integrate a tablet PC they already own prior to building the robot, which would allow them to save these costs entirely.

Any software we used in creating the robot was entirely open source.

For the building instructions of the system, we chose to venture down two completely different paths simultaneously.

On the one hand, we created a step-by-step instruction manual in the form of a PDF document, including images and CAD screenshots to illustrate the building steps.

On the other hand, we also chose to create a virtual reality (VR) assembly guide using the Unreal Engine that can help a user to understand and practice all assembly steps in the correct order.

Following this outline, our objectives for the semester shaped up as follows.

**Folie „Main Objectives"**

First of all, our hardware team was tasked to improve upon the previous semester's group's concept for a DIY telepresence robot before building an actual functioning prototype.

Our other main objective was to create a step-by-step virtual reality assembly guide using the Unreal Engine. This task also came with two optional objectives that we managed to complete by the end of the semester: the implementation of a replay system that allows for users to skip back and forth between instruction steps in the VR-environment and to rewatch an animation detailing a building step if something was unclear the first time around.

We also included a feedback system that tells the users whether they assembled the parts correctly.

**Folie „Concept Iteration“**

Our work on the hardware began with an iteration of the previous concept design, which you can see on the left, which we turned into the one you can see on the right.

Our new system features increased durability and stability thanks to the sandwich structure in the bottom. It is height-adjustable and taller than the previous version while also remaining more cost-efficient.

A complete inventory of the exact parts we used is part of the instruction manual.

**Folie „Hardware Assembly“**

In the beginning of our assembly process, we pre-manufactured our wooden and Plexiglas pieces by manually drilling holes into them and sawing them to the correct length.

Then we assembled the sandwich structure, added the internal electronics and motors, before mounting a cover plate and the lower tube.

We added a tube adapter from the hardware store to connect the two tubes, whose rubber seal ring provides enough flexibility to change the upper tube’s relative position.

We finally added the upper tube, tablet holder, tablet, and some wheels, and began conducting our drive tests. The audio system was also added at a later point.

**Gruppenbild und Video**

For creating some of the pieces, we used the 3D printer and CNC milling machines at the IMI. Alternatively, these pieces can also be purchased online or finished manually.

**Folie „Internal Electronics“**

The internal electronics that make our robot work include a Wi-Fi-capable Arduino, on top of which we stacked a motor driver shield that drives two powerful DC motors with integrated gearboxes that provide enough torque to propel the robot.

Both the driver shield and Arduino are powered by a power bank each. Not pictured here are some additional components required to make the system work, like a DIY transistor bridge that we had to solder onto two pins of the Arduino to prevent the power banks from automatically shutting down once the motors were stopped. And two ultrasonic sensors — one in the back and one in the front of the robot — to warn the Arduino about impending collisions.

**Folie „System Layout“**

Here you can see the electronics integrated into the complete system.

**Video**

In addition to assembling the hardware, we also created a CADmodel of the entire assembly, including all relevant systems.

**Folie „CAD Model contains all Information for CAM and VR“**

The CAD model was highly useful for two applications: we used it to generate some CAM data that we needed to operate the IMI's 3D printer and CNC milling machine, but it was also required for the VR assembly guide itself.

We converted the assembly into a STP file, which we imported into the Unreal Engine via the Datasmith plugin. Now we could use the CAD model and all of its subsystems inside the VR environment.

This procedure essentially makes our VR environment truly universal, as different CAD models for entirely different technical systems could be imported into the engine in order to create their own assembly guides. The only thing left to do would be to manually restore a hierarchy in between the components to ensure a realistic assembly sequence, as the relations from the CAD model get lost in translation.

**Folie „UML Diagram — Tree Structure of Models in UE“**

While the hardware team was still busy assembling the robot, our software experts began laying out the concept for our software structure in the form of a UML diagram that shows the different classes and functions required to make our C++ code work.

**Folie „Level Design in Unreal Engine“**

We also designed a level environment inside the Unreal Engine that features two workbenches for the robot and the parts, and this control panel with four buttons to allow the user to start the assembly or disassembly process, to activate the replay system, or to undo the last actions if mistakes were made.

**Folie „VR Tests“ und Bilder**

After many hours of coding and testing, we finally managed to record the following footage of a complete working assembly and disassembly process.

**Video (8:00-9:30)**

We began by disassembling a complete model of our telepresence robot. The yellow markings always indicate which parts have to be removed next from the system. So, we're currently at the sound system here, with the right and the left loudspeaker.

Now we remove the tablet holder.

And there is basically a number of ways we could go now; we chose the top tube here as well as the tube adapter.

And here you can see how a piece accidentally gets misplaced — there our user lost it, so we just redo the step. The piece is back, where it was initially, can be picked up again and is placed here.

Now, as you can see, we can also remove the electronics, or at least some of the components, like the power banks and the motors from the system. We chose to place them on this workbench instead of the other for visibility, but ultimately both would be possible.

Now, removing the lower tube, the tube socket, and finally the base plate completes the entire disassembly process.

**Video (9:30-12:20)**

Now you're going to see what the assembly process looks like in VR. So basically, we start the assembly by pushing that button, which decomposes the complete model you just saw into the pile of parts from earlier. The blue markings always indicate which piece has to be added to the system next.

So now we're here with the lower tube socket, now the lower tube.

And the important thing to notice about this is that there is always this sort of "blue ghost" or robot that essentially tells us where to place the next parts.

These animations were created inside the Unreal Engine by reverse-playing the recordings of the disassembly process we just did. So basically, in order to generate these assembly instructions, all you have to do is to once, yeah, deconstruct the entire CAD model, and then we end up with something like this.

So now we're back at the electronics. The green thing is the Arduino, which is placed in the front.

Both of the electric motors are added. Now the front wooden support structure. Next piece is the top plate, which has to be lowered over the bottom tube.

And, as you can see right here, I made a mistake — I didn't place the piece correctly. So, our system lets us know by just snapping it right back to the position where it last was before that.

This is the rear wooden support structure, which holds the entire back of the robot together, and our friendly support helper here tells us that we have to add those side pieces next.

Now we continue with the wheels. Notice how this is the exact order in which we disassembled the system in the earlier part of the video.

Now this is the swivel caster.

We move on to the ultrasonic sensors; there are two of them. One of them is placed in the back of the robot, the other one belongs in the front.

Then we add the tube adapter.

The top tube.

The tablet holder.

In real life, you could also just put those two together first before inserting the top tube — it doesn't really matter. Now you can take the pieces of the sound system and add them, including the microphone. And the final step would be to attach the tablet PC.

**Folie Me and the Boys building a Telepresence Robot**

That's it — thanks for watching. If you're curious about the other projects here at the IMI, please don't forget to check out the other videos that show the results of previous semesters' groups' work.