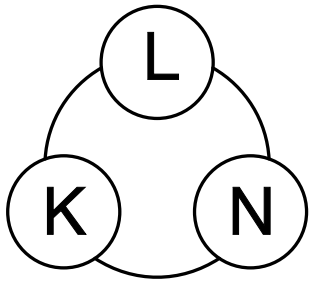

Technische Universität München
Lehrstuhl für Kommunikationsnetze
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Bachelor's Thesis

An augmented reality-based mobile application for visualizing robot models and robot states

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Begin:	15. June 2020
End:	15. November 2020

With my signature below, I assert that the work in this thesis has been composed by myself independently and no source materials or aids other than those mentioned in the thesis have been used.

München, 15.11.2020	
Place, Date	Signature

München, 11.06.2014	
Place, Date	Signature

Kurzfassung

A short abstract of the thesis in German.

Abstract

A short abstract of the thesis in English.

Preface

A short preface over me and why I am here

Acknowledgement

A short acknowledgement too all the people I wand to mention

Contents

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Chapter 1

Introduction

This chapter should give a short overview over the whole thesis. It should provide background information on the thesis topic, introduce the task definition and give a short outlook on the rest of the thesis.

Chapter 2

Background

2.1 Content

In this chapter, all background necessary to understand the thesis are introduced. The level of detail is such that a colleague with similar background (no specialist!) is capable of understanding the contribution and impact of the thesis. A discussion of state-of-the-art solutions (e.g. literature research) is often helpful. Problems of the state-of-the-art are typically discussed and the contribution of the thesis is introduced in detail.

Chapter 3

Pre-Survey

In order to discuss which functions are particularly useful for AR applications, a study with a questionnaire was set up at the beginning of the thesis. The study was held within the development department of Franka Emika and was, first of all, to check if a benefit is seen in an Augmented Reality application. There were 12 employees involved, all of whom routinely work with the Panda and know the daily operation problems well.

It was checked which functions are considered to be especially important. Specifically, they were asked which problems often occur when working with the panda. Problems with the joint limits and problems with the payload were queried. As you can see in Figure 3.1, it turned out that errors due to joint limits were a medium to the large problem for all those questioned.

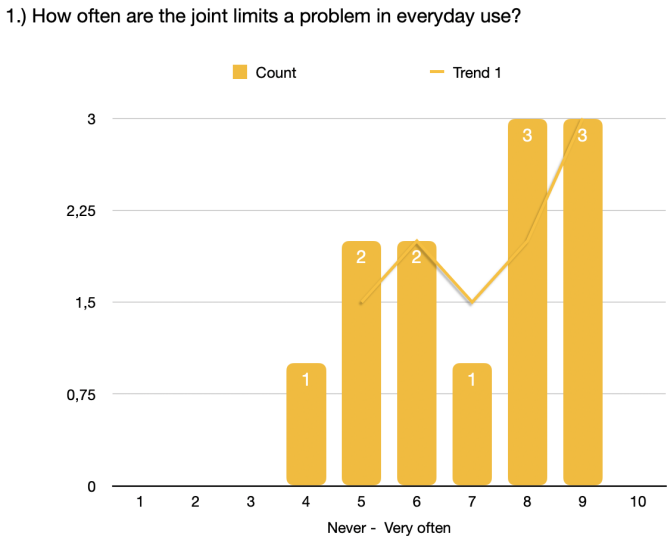

Figure 3.1: Pre-Survey: Question 1

In the case of errors caused by the payload, the camps are divided into the group with no problems, and the larger group that regularly receives errors here (Figure 3.2).

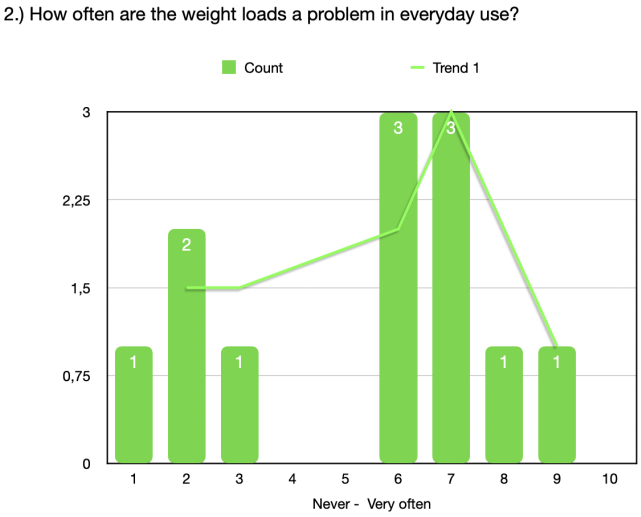

Figure 3.2: Pre-Survey: Question 2

Afterward, it was asked how useful a "Task-Preview" function and a recording function would be. The "Task-Preview" function would mean that the Panda arm's digital model performs a movement sequence to show the user what the movement would look like and if it would work. The recording function should remember the angles of the individual joints per frame and play them back if desired. As Figure 3.3 illustrates, almost all respondents found the "Task-Preview" function useful to very useful.

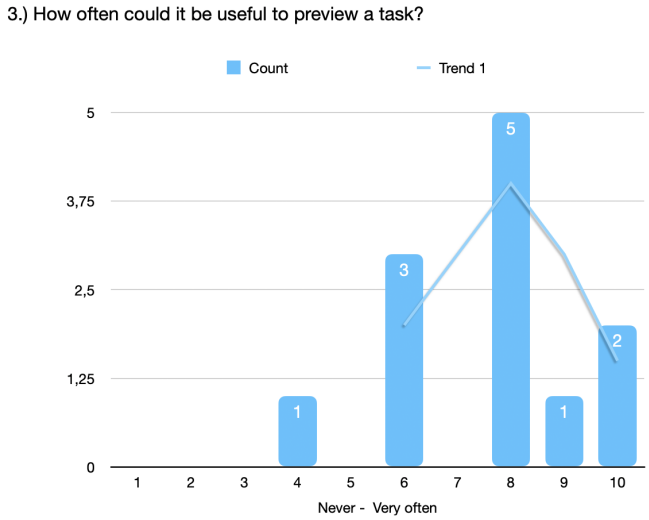

Figure 3.3: Pre-Survey: Question 3

The recording function, on the other hand, was rated rather neutrally. Figure 3.4 depicts that.

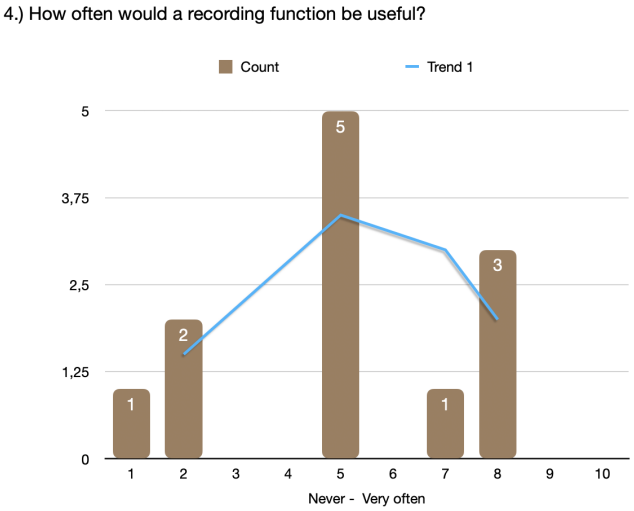

Figure 3.4: Pre-Survey: Question 4

These four functions could be ordered by preference in the next question. This resulted in the following Table 3.1 from important to worthless:

The overall question was also asked for how great the benefit of an AR application is evaluated. Here in Figure 3.5, 9 out of 12 respondents said they saw a benefit or a great benefit in such an application.

Finally, the participants of the study could give personal feedback. In doing so, constructive suggestions were given. The most asked for was a Panda arm model that can be placed in the world and manipulated afterward. Furthermore, all effects on the Panda arm should be visible in the application. Not only the weight to be carried but all forces acting on the panda. A "Garmi" demonstration was also suggested.

This study has not only confirmed the broad benefits of an AR application. However, it has also clearly pointed out that the panda's daily users may need certain functions to work better with a collaborative robot.

Functions	**Preference**
Joint limit ads	1.
Task preview	2.
Weight load ads	3.
Recording function	4.

Table 3.1: Preference of functions

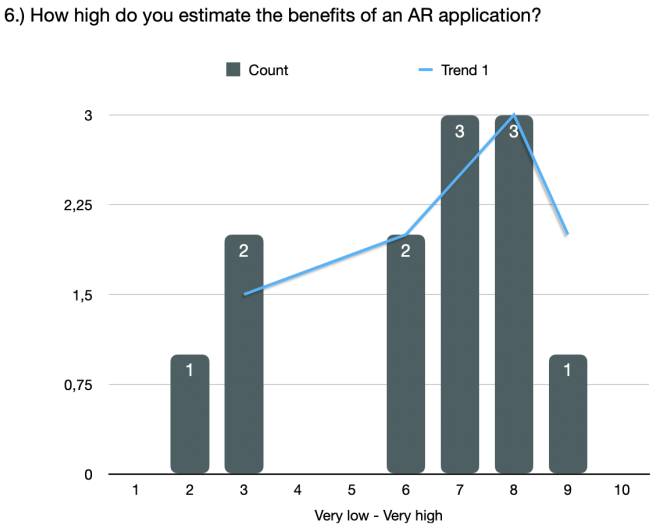

Figure 3.5: Pre-Survey: Question 4

Chapter 4

Implementation and Results

4.1 Development environment

Details regarding implementation and/or simulation are given in this chapter. The considered setup and the parameters used are introduced and discussed. Also, the general evaluation methods can be presented. (Note: Code should not be part of this chapter. If it makes sense to introduce it into the thesis, it should be placed in the appendix.)

What makes Unity special? Why did I choose Unity? Which frameworks do I use in Unity? Why do I use these frameworks? How do they work and what do these frameworks contain?

4.2 Structure of the application

How is an application in Unity structured? How is the application structured? Which main functions are located in which scene?

4.3 Start Screen

What does this do? How does the scene relate to other scenes How is it done?

4.4 Menu

What does this do? How does the scene relate to other scenes How is it done?

4.5 Panda Demo

What does this do? How does the scene relate to other scenes How is it done?

4.6 Garmi Demo

What does this do? How does the scene relate to other scenes How is it done?

4.7 Panda Inside

What does this do? How does the scene relate to other scenes How is it done?

Chapter 5

Methodology

Here I will present what I am using to get results -¿ User Study with Survey

5.1 User Study

Here I am going to present the study with all details

1. What did I do (with detailed structure of the Experiment)

5.2 Results

Here I will present the results of the user study

Chapter 6

Conclusions and Outlook

The thesis is concluded here. The considered problem is repeated. The contribution of this work is highlighted and the results are recapitulated. Remaining questions are stated and ideas for future work are expressed.

Appendix A

Appendix for important Code

The appendix may contain some listings of source code that has been used for simulations, extensive proofs or any other things that are strongly related to the thesis but not of immediate interest to the reader.

Appendix B

Notation und Abkürzungen

This chapter contains tables where all abbreviations and other notations like mathematical placeholders used in the thesis are listed.

AP	Access Point
AR	Augmented Reality
CQI	Channel Quality Indicator
DCI	Downlink Control Information
D-SR	Dedicated Scheduling Request
D2D	device to device
eNodeB	evolved Node B or E-UTRAN Node B
FDD	Frequency Division Duplexing
H-ARQ	Hybrid-Automatic Repeat Request
IoT	Internet of Things
LTE	Long Term Evolution
MCS	Modulation and Coding Scheme
OFDM	Orthogonal Frequency Division Multiplexing
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
SC-FDMA	Single Carrier Frequency Division Multiple Access
SR	Scheduling Request
SRS	Sounding Reference Signal
TDD	Time Division Duplexing
UE	User Equipment