

Master Thesis

**Autonomous Object Training and Detection System with Convolutional Neural Networks**

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Statement

I confirm that I have written this thesis on my own. No other sources were used except those referenced. Content which is taken literally or analogously from published or unpublished sources is identified as such. The drawings or figures of this work have been created by myself or are provided with an appropriate reference. This work has not been submitted in the same or similar form or to any other examination board.

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# Introduction / Einführung

In this thesis, an object training and detection system is developed to overcome the challenge of retraining the Convolutional Neural Networks based on a different learning target. Object detection is the critical area of computer vision that has numerous practical applications in various fields, such as autonomous driving, robotics, and surveillance. CNNs have emerged as one of the most effective methods for object detection and recognition due to their ability to learn and extract meaningful features from images. However, retraining a CNN model for object detection can be a time-consuming and resource-intensive process, requiring a large amount of labeled data and computational resources.

Moreover, the requirement of significant computing power and large labeled datasets has made CNN training prohibitive for many developers and researchers who lack the necessary resources. Despite the increasing popularity of CNN models in recent years, the need for these resources has limited their use in a wide range of applications.

Most of well-known pre-trained CNN models, for instance GoogleNet,

To address this challenge, t

To address this challenge, transfer learning has become an increasingly popular technique in recent years. Transfer learning involves using a pre-trained CNN model as a starting point and fine-tuning it on a new dataset for a specific task. This approach has several advantages over retraining the entire CNN model from scratch, including reducing the number of resources required, requiring less labeled data, and achieving comparable performance to training the model from scratch.

The transfer learning approach has proven to be particularly effective in cases where the labeled data is limited, and fine-tuning a pre-trained CNN model with a limited dataset is a more practical solution. In recent years, researchers have explored several transfer learning methods, including fine-tuning, feature extraction, and domain adaptation, to improve the performance of object detection and recognition models.

Fine-tuning involves using a pre-trained model as a starting point and then training the entire model with new weights for the specific task. The new layers are initialized randomly and trained using the labeled data for the new task. Feature extraction involves using the pre-trained model to extract features from the images and training a new model on these features for the specific task. Domain adaptation involves adapting the pre-trained model to a new domain with limited labeled data, using techniques such as domain adversarial training.

In recent years, several transfer learning methods have been proposed for object detection and recognition tasks, such as Faster R-CNN, YOLO, and SSD, which have achieved state-of-the-art performance on benchmark datasets. These methods have been used in various applications, such as autonomous driving, facial recognition, and pedestrian detection.

However, one of the major challenges in object detection and recognition is the difficulty in retraining CNNs with limited labeled data. In many real-world scenarios, obtaining a large amount of labeled data for a specific task is challenging and costly. Therefore, transfer learning has become a crucial technique for addressing this challenge. By leveraging pre-trained models on large datasets, transfer learning allows us to adapt these models to new tasks with limited labeled data.

In the proposed thesis, we will explore the effectiveness of transfer learning for object detection and recognition tasks. We will develop an object detection and recognition system using transfer learning that will significantly reduce the number of resources and labeled data required for retraining CNN models. The main goal of the thesis is to demonstrate the feasibility and effectiveness of using transfer learning for object detection and recognition tasks.

# Theoretical Background

This section will provide a detailed overview of the key concepts and theories that are relevant to the study of

our study of machine learning in the context of image classification. We will begin by exploring the fundamental principles of artificial neural networks, the basic building blocks of many modern machine learning algorithms. We will then delve into the specific types of neural networks commonly used for image classification, including convolutional neural networks and deep belief networks. Finally, we will discuss the various optimization techniques and evaluation metrics used in machine learning, highlighting the key considerations and tradeoffs involved in selecting the most appropriate method for a given application. Through this discussion of theoretical background, we aim to provide a comprehensive understanding of the underlying concepts and techniques that inform our research, and to contextualize our study within the broader field of machine learning and artificial intelligence.

## Machine Learning

Machine learning has found its applications in various fields such as image recognition, natural language processing, fraud detection, recommendation systems, and many more. With the exponential growth of data, machine learning algorithms have become increasingly important in enabling businesses to extract insights from large and complex datasets. In addition, machine learning has the potential to transform industries, including healthcare, finance, transportation, and manufacturing, by improving accuracy, efficiency, and cost-effectiveness. As technology continues to advance, the impact of machine learning is expected to expand further, and it will undoubtedly play a significant role in shaping the future of our world.

In 1959, the paper "Some studies in machine learning using the game of checkers" by Samuel (1959) introduced the concept of machine learning, a subfield of artificial intelligence, by demonstrating how a computer program could learn to play checkers through a process of trial and error. Samuel (1959) proposed a machine learning algorithm for playing checkers that involved the use of a tree of moves. The tree of moves is a hierarchical structure that represents all possible moves that can be made in a game of checkers. The tree starts at the root, which represents the current state of the game, and branches out into nodes that represent all possible moves that can be made from that state. The algorithm uses a heuristic function to evaluate each node in the tree, estimating the expected outcome of the game if that move is made. The heuristic function is based on a set of features that describe the current state of the game, such as the number of pieces on the board, the position of the pieces, and the potential for capturing the opponent's pieces. The algorithm recursively evaluates each node in the tree, selecting the move that leads to the highest expected outcome based on the heuristic function. The tree of moves enables the algorithm to explore all possible moves and select the best move based on the expected outcome of the game. The concept of the tree of moves is a fundamental component of many machine learning algorithms for game playing, including the minimax algorithm and its variants. It enables the algorithm to explore all possible moves and select the best move based on a heuristic evaluation of the expected outcome of the game. His paper played a crucial role in the development of machine learning as a field of study. By demonstrating the effectiveness of learning algorithms in the context of checkers, Samuel introduced fundamental concepts that have since become the foundation of modern machine learning techniques. His work laid the groundwork for subsequent research in the field and opened up new possibilities for the application of machine learning across a range of domains (Samuel, 1959).

## Neural Networks

Neural networks are a type of machine learning algorithm that are inspired by the structure and function of the human brain. They are composed of interconnected nodes, called neurons, that process information by transmitting signals through weighted connections. Neural networks can be used for a wide range of tasks, including pattern recognition, image and speech processing, and natural language understanding. One of the key advantages of neural networks is their ability to learn and generalize from data, making them well-suited for complex problems that are difficult to solve with traditional algorithms.

The concept of neural networks dates back to the 1940s, with the development of the McCulloch et al., (1943)’s neuron model, which formed the basis of early artificial neural networks. In 1958, Rosenblatt (1958) introduced the perceptron, a single-layer neural network that could learn to classify input patterns into two categories. This was a major breakthrough in the field of neural networks, and it paved the way for the development of more advanced models, such as multi-layer perceptrons and convolutional neural networks (McCulloch et al., 1943; Rosenblatt, 1958).

In the 1980s, the backpropagation algorithm was developed as a way to train multi-layer neural networks, enabling them to handle more complex data and achieve higher levels of accuracy. This algorithm uses gradient descent to adjust the weights of the connections between neurons, based on the error between the predicted output and the actual output. The backpropagation algorithm has been widely used in deep learning, which involves training neural networks with multiple layers of processing (Rumelhart et al., 1986).

Recently, neural networks have achieved remarkable success in a variety of applications, including image and speech recognition, natural language processing, and robotics. For example, convolutional neural networks have been used to achieve state-of-the-art performance in object recognition tasks, while recurrent neural networks have been used to generate natural language text. These breakthroughs have led to widespread interest and investment in neural networks, and they are likely to play an increasingly important role in many areas of research and industry.

## Convolutional Neural Network

The paper "Gradient-based learning applied to document recognition" by LeCun et al., (2015) presents a deep neural network architecture specifically designed for processing two-dimensional inputs, such as images. The network is composed of multiple layers, including convolutional layers, pooling layers, and fully connected layers. The convolutional layers use a small set of learnable filters to convolve with the input image, extracting local features that are invariant to small translations in the image. The pooling layers then down sample the feature maps, reducing the dimensionality of the data while maintaining the spatial structure. Finally, the output of the convolutional and pooling layers is flattened and fed into fully connected layers, which perform the final classification. The approach was significant in that it greatly improved the performance of image recognition systems compared to previous methods. The use of convolutional layers allowed the network to effectively capture the spatial structure of images and learn local features that were invariant to small translations in the image. This made the network much more robust to variations in the input data and enabled it to generalize well to new images. To train the network, LeCun et al., (2015) used a variant of stochastic gradient descent called the backpropagation algorithm. The network was trained on a large dataset of handwritten digits, known as the MNIST dataset. The training process involved iteratively adjusting the weights of the network to minimize the difference between the predicted outputs and the true labels. LeCun et al., (2015)'s paper was a ground-breaking contribution to the field of computer vision and has had a significant impact on the development of deep learning techniques for image analysis. The CNN architecture introduced in the paper has since become a fundamental building block in many state-of-the-art image recognition systems (LeCun et al., 2015).

## Transfer Learning

Transfer learning is a subfield of machine learning that has gained increasing attention in recent years due to its ability to improve the performance of models on new tasks with limited labelled data. The concept of transfer learning is based on the idea that knowledge learned from one task can be utilized to improve the performance of a related task. In other words, the learned knowledge is transferred from the source task to the target task, reducing the need for extensive training on the target task. In transfer learning, a pre-trained model is used as a starting point, and then it is fine-tuned on a new dataset or task. The pre-trained model is typically trained on a large dataset for a related task, such as image classification or natural language processing. By using a pre-trained model, transfer learning enables models to learn a generalized representation of the data, rather than learning from scratch on the target task. This approach can significantly reduce the training time and computational resources required to train a model from scratch, and it can also lead to better performance on the target task. The concept of transfer learning has been applied to a wide range of machine learning tasks, including image classification, object detection, natural language processing, and speech recognition. In each of these domains, transfer learning has been shown to improve the performance of models on new tasks and reduce the amount of labelled data required for training.

TODO [Write about type of transfer learning]

"Learning Transferable Features with Deep Adaptation Networks" is a seminal research paper by Long et al., (2015) that proposed a deep adaptation network (DAN) for transfer learning in image classification. The authors introduced a novel approach that leverages a pre-trained CNN model as a starting point and fine-tunes it on a new domain using a domain adaptation technique. The method also incorporates a joint adaptation approach that learns a shared feature representation for multiple domains, improving the transferability of learned features.

The primary motivation for the study was the challenge of applying CNN models to new domains that are significantly different from the training data. In such cases, retraining a CNN model from scratch on the new data can be impractical, especially when the amount of available data is limited. Transfer learning, which involves utilizing knowledge learned from one task to improve the performance of a related task, has emerged as a promising solution to this challenge.

Long et al. demonstrated that their DAN model achieved state-of-the-art performance on several benchmark datasets, including the Office-31 and Caltech-256 datasets. They evaluated their approach on four different transfer learning scenarios, including domain adaptation, unsupervised domain adaptation, multi-source adaptation, and cross-modality adaptation. In all scenarios, the proposed method achieved better performance than existing approaches.

The authors also conducted extensive experiments to analyse the effectiveness of their approach. They demonstrated that the joint adaptation approach improved the transferability of learned features, especially when there is a significant domain shift between the source and target domains. They also compared the DAN model to traditional fine-tuning and feature extraction approaches and showed that the DAN model achieved better performance, demonstrating the importance of domain adaptation in transfer learning.

Overall, the research paper by Long et al. demonstrates the effectiveness of transfer learning in image classification and highlights the importance of domain adaptation in improving the transferability of learned features. The proposed DAN model provides a promising solution to the challenge of applying CNN models to new domains, reducing the need for large amounts of labelled data and improving the adaptability of deep learning models.

# Requirements Analysis / Anforderungsanalyse

The requirement analysis asks for the “what”, not for the “how”! Die Anforderungsanalyse fragt nach dem „was“, nicht nach dem „wie“.

## General Objectives / Generelle Zielsetzung

What is to be investigated / achieved? Was soll untersucht / erreicht werden?

General structure of the system / Genereller Aufbau des Systems

Initial state / Istzustand, Ausgangszustand

Previous work / Vorhergehende Arbeiten

Description of the work environment / Umfeldbeschreibung

* Existing hardware and software infrastructure, general conditions / Vorhandene Hardware- und Software-Infrastruktur, Rahmenbedingungen
* …

Example / Beispiel:

In this work, a software has to be developed that enables the copying of files from a client to a server and vice versa. The software shall therefore consist of a client component and a server component. With the client component, the files are uploaded, downloaded and manipulated on the server. The server component offers a web interface to allow the administrator a remote configuration of the server. The server shall support a multi-client communication.

Im Rahmen dieser Arbeit soll eine Software entwickelt werden, mit der es möglich ist, Dateien von einem Server aus dem Internet auf einen Client herunter zu kopieren und Dateien vom Client auf diesen Server hoch zu kopieren. Die Software soll deshalb aus einer Clientkomponente und einer Serverkomponente bestehen. Mit Hilfe der Clientkomponente werden die Dateien auf den Server hoch und herunterkopiert sowie manipuliert. Die Serverkomponente besitzt für die Konfiguration ein Webinterface, um dem Administrator eine entfernte Konfiguration zu ermöglichen. Der Server soll weiterhin die Kommunikation mit mehreren Clients unterstützen.

## Clarifying the Requirements / Klärung der Anforderungen

Through discussions with supervisors and literature research from books, papers – IEEE (www.ieee.org), ACM (http://dl.acm.org/), access via FRA-UAS Intranet – as well as standardisation organisations – ETSI (http://www.etsi.org/), ITU-T (http://www.itu.int/en/ITU-T/Pages/default.aspx), 3GPP (http://www.3gpp.org/), IETF (www.ietf.org) – the requirements are to be defined (Trick and Weber 2015).

Durch Gespräche mit den Betreuern und Literaturrecherchen in Büchern, Aufsätzen – IEEE (www.ieee.org), ACM (http://dl.acm.org/), Zugriff aus FRA-UAS-Intranet – sowie bei Standardisierungsorganisationen – ETSI (http://www.etsi.org/), ITU-T (http://www.itu.int/en/ITU-T/Pages/default.aspx), 3GPP (http://www.3gpp.org/), IETF (www.ietf.org) – sollen die Anforderungen definiert werden (Trick und Weber 2015).

Requirements for the project / Anforderungen an das Projekt:

* Clarification of the main functionality / Klärung der Hauptfunktionalität
* Narrowing the problem area / Problemfeldabgrenzung
* Derivation of functional requirements / Ableitung der funktionalen Anforderungen
* Derivation of non-functional requirements / Ableitung der nicht funktionalen Anforderungen

Example / Beispiel:

The developed software shall allow storing files to the server in the Internet. Furthermore, it shall be possible to copy files from the client to the server and vice versa, to delete files, and to rename files. The files should be stored on the server in the Internet. The software consists of a client software on the computer of the user and a server software on the server in the Internet.

The access to the files should be allowed with a user name and password combination. Anyone who knows this username and password, can access the files on the server with the client software, even from another computer.

The user manages his files with a graphical user interface that supports all the addressed functionalities. With this software, it shall also be possible to exchange files with other servers in the Internet.

The server shall support to store files from multiple users. The administrator of the server shall have the possibility to configure the server with a web interface. He can manage the users and the passwords on the server, can define the files which can be accessed by a user, the number of files and the size of the files which can be copied by a specific user.

Die zu entwickelnde Software soll es ermöglichen, Dateien auf einem Server im Internet zu speichern. Sie soll es erlauben, die Dateien auf einen Server im Internet zu kopieren, sie zu löschen, sie umzubenennen und die Dateien aus dem Netzwerk herunter auf den Client zu laden. Die Daten sollen dabei zentral auf einem Server im Internet gespeichert werden. Die Software besteht aus einer Client-Software auf dem Benutzerrechner und einer Server-Software auf dem Server im Internet.

Der Zugriff auf die Dateien soll mit einer Kombination aus Benutzername und Passwort erlaubt werden. Jeder, der diesen Benutzernamen und das Passwort kennt, kann mit der Client-Software, auch von einem anderen Computer aus, Zugriff auf die Dateien auf dem Server erhalten.

Der Benutzer soll seine Dateien mithilfe einer grafischen Benutzeroberfläche verwalten, die alle der oben genannten Aktionen unterstützen muss. Mit dieser Software soll auch die Möglichkeit bestehen, Dateien auf andere Internetserver zu kopieren.

Der Server im Internet soll die Möglichkeit besitzen, Dateien mehrerer Benutzer zu speichern. Der Administrator des Servers soll mit einem Webinterface die Möglichkeit besitzen, den Server zu konfigurieren, er soll die Benutzer mit ihren Namen und Passwörtern verwalten und festlegen können, welcher Benutzer welche Dateien in welcher Anzahl und Größe manipulieren und kopieren darf.

## Time frames / Zeitliche Rahmenbedingungen

In the section time frames, the timetable including the start and end time and the milestones of work are presented. One week after the start of work, the requirements analysis must be submitted to the supervisor. Four weeks (three weeks for bachelor) before the final deadline, a draft has to be submitted. Two weeks before the deadline, the complete thesis draft must be submitted. These dates must also be part of the requirements analysis.

Im Abschnitt „Zeitliche Rahmenbedingungen“ wird die Zeitplanung festgehalten, dazu zählen der Start- und Endzeitpunkt der Arbeit und die Meilensteine. Eine Woche nach Beginn der Arbeit ist die Anforderungsanalyse beim Betreuer abzugeben und vier Wochen (drei Wochen für Bachelor) vor Abgabetermin der Arbeit ist der Entwurf der Ausarbeitung beim Betreuer abzugeben. Zwei Wochen vor dem Endtermin ist die vollständige schriftliche Ausarbeitung als Entwurf abzugeben. Diese Termine müssen auch in den zeitlichen Rahmenbedingungen der Anforderungsanalyse festgehalten werden.

Example / Beispiel:

Milestones:

10.05.2015 to 17.05.2015: Analysis of the requirements

17.05.2015: Submission of the requirements analysis

10.05.2015 to 10.06.2015: Literature review and learning the theoretical background

10.05.2015 to 27.07.2015: Writing up the thesis and the documentation

11.06.2015 to 30.06.2015: Elaborating of the concept and planning of the prototype

11.06.2015 to 10.08.2015: Implementation of the prototype

27.07.2015: Submission of the Thesis draft to supervisor

27.07.2015 to 10.08.2015: Revise the thesis based on the proposals from the supervisor

10.08.2015: Submitting the Thesis to the examination office

Meilensteine:

10.05.2015 bis 17.05.2015: Analyse der Anforderungen

17.05.2015: Abgabe der Anforderungsanalyse

10.05.2015 bis 10.06.2015: Literaturrecherche und Einarbeiten in die theoretischen Grundlagen

10.05.2015 bis 27.07.2015: Anfertigung der schriftlichen Ausarbeitung und der Dokumentation

11.06.2015 bis 30.06.2015: Ausarbeitung des Konzepts und Planung des Prototyps

11.06.2015 bis 10.08.2015: Implementierung des Prototyps

27.07.2015: Abgabe der schriftlichen Ausarbeitung als Draft an den Betreuer

27.07.2015 bis 10.08.2015: Einarbeiten der Vorschläge des Betreuers

10.08.2015: Ende der Bearbeitungszeit und Einreichen der Ausarbeitung im Prüfungsamt

## Target State / Target Objective / Zielzustand / Angestrebtes Ziel

Example / Beispiel

For the implementation of the prototype, the final state shown in Figure 3.1 is expected. A computer on the Internet is provided with the server component of the developed prototype and a computer in the lab network with the client component. By using the graphical user interface, the user of the client computer can copy files from the client computer to the server and vice versa. The server shall be multi-client capable but should provide only the files owned by the user to this user. For security reasons, the client must authenticate to the server before it can download, upload and manipulate files.

With the help of the graphical user interface on the client, the uploaded files can be stored on the server, deleted, renamed, downloaded and managed. The administrator of the server shall have the possibility to configure the server via a web interface. He can manage the users and the passwords on the server, defines the files that can be accessed by a user, the number of files and the size of the files which can be copied by a specific user.

Für die Realisierung des Prototypen wird der in Bild 3.1 abgebildete Endzustand erwartet. Ein Computer im Internet wird mit der Server-Komponente des entwickelten Prototypen ausgestattet und ein Computer im Labornetz mit der Client-Komponente. Mithilfe der grafischen Benutzeroberfläche kann der Benutzer des Clientcomputers das Kopieren von Dateien vom Clientcomputer zum Server und umgekehrt verursachen. Der Server soll multiclient-fähig sein, aber jedem Benutzer nur die durch den Benutzer hochgeladenen Dateien bereitstellen. Aus Sicherheitsgründen muss sich der Client bzw. der Benutzer beim Server authentifizieren, bevor er Dateien hochladen und herunterladen bzw. manipulieren kann.

Die hochgeladenen Dateien sollen, mit der Hilfe der grafischen Benutzeroberfläche auf dem Client, auf dem Server im Internet gespeichert, gelöscht, umbenannt, heruntergeladen und verwaltet werden können. Der Administrator des Servers soll mit einem Webinterface die Möglichkeit besitzen, den Server zu konfigurieren, er soll die Benutzer mit ihren Namen und Passwörtern verwalten und festlegen können, welcher Benutzer welche Dateien in welcher Anzahl und Größe manipulieren und kopieren darf.

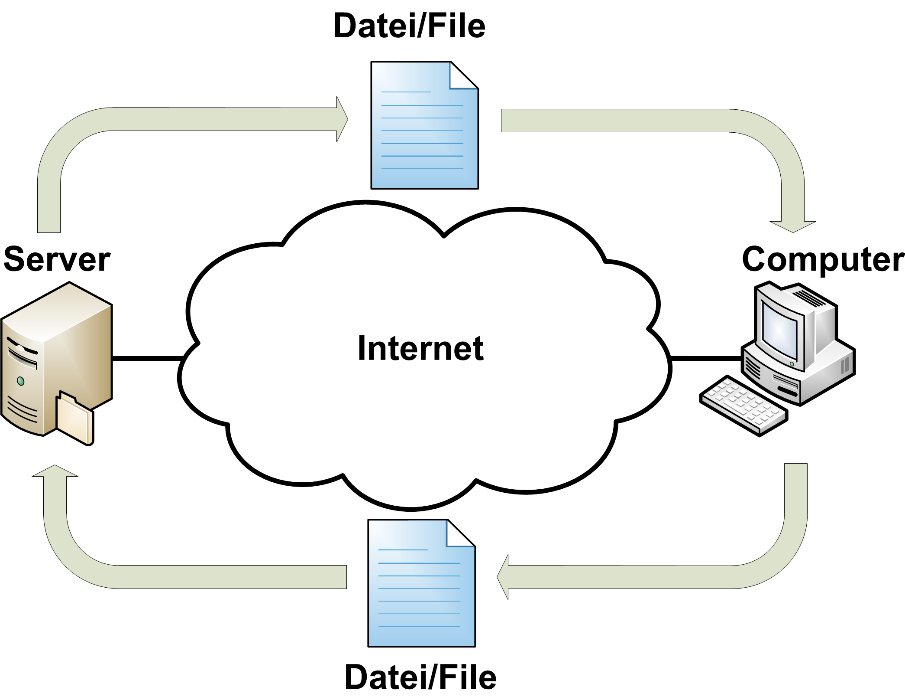


Figure 3.1: Target system in an overview / Bild 3.1: Zielsystem im Überblick

## Use Cases for the Prototype / Anwendungsfälle für den Prototyp

Investigated and prototypically implemented cases / Welche Fälle werden untersucht bzw. prototypisch implementiert?

Example / Beispiel:

For a demonstration of the functionality, a prototype of the client software and a prototype of the server software has to be implemented.

* The prototype of the server software has the ability to connect with multiple clients.
* With the help of the client software a user can connect to the server using user name and password
* …

The client software has a graphical interface with the functionality to:

* Log on to the server
* Log out of the server
* Stopping the Client software
* Manage multiple users
* Managing multiple server profiles for each user
* Selecting files on the local file system for upload or manipulation
* Selecting files on the server for download or manipulation
* Rename, delete and copy files on the local file system
* Rename, delete and copy files on the server
* Upload the selected files to the server
* Download the selected files from the server
* Cancel the upload and download process
* Selecting / creating the destination directory on the server
* Selecting / creating the destination directory on the client
* …

The server software with the Web Interface has the functionality to:

* Authenticating the user
* Establishing multiple connections simultaneously with the clients
* Manage multiple users with its files via the web interface
* Managing the directory structure of each user
* Web-based configuration of the server
* Secure transfer of files
* Repeat the file transfer on errors
* …

Zur Demonstration der Funktionalität werden Prototypen der Client-Software und der Server-Software implementiert.

* Der Prototyp der Server-Software besitzt die Möglichkeit, Verbindungen mit mehreren Clients einzugehen.
* Ein Benutzer kann sich mit der Client-Software mithilfe seines Benutzernamens und seines Passwortes beim Server anmelden.
* …

Die Client-Software hat eine grafische Benutzeroberfläche mit der Funktionalität zum:

* Anmelden am Server
* Abmelden vom Server
* Beenden der Client-Software
* Verwalten mehrere Benutzer
* Verwalten mehrerer Serverprofile je Benutzer
* Auswählen von Dateien auf dem lokalen Dateisystem für den Upload bzw. die Manipulation
* Auswählen von Dateien auf dem Server für den Download bzw. die Manipulation
* Umbenennen, löschen und kopieren von Dateien auf dem lokalen Filesystem
* Umbenennen, löschen und kopieren von Dateien auf dem Server
* Hochladen der ausgewählten Dateien zum Server
* Herunterladen der ausgewählten Dateien vom Server
* Abbrechen des Hochlade-, Herunterladevorgangs
* Auswählen / Erstellen des Zielverzeichnisses auf dem Server
* Auswählen / Erstellen des Zielverzeichnisses auf dem Client
* …

Die Server-Software mit dem Webinterface hat die Funktionalität zum:

* Authentifizieren der User
* Aufbauen mehrerer Verbindungen gleichzeitig mit den Clients
* Verwalten mehrerer Benutzer mit seinen Dateien über das Webinterface
* Verwalten der Verzeichnisstruktur jedes Benutzers
* Webbasierte Konfiguration des Servers
* Sicheres Übertragen von Dateien
* Wiederholen der Dateiübertragung bei Fehlern
* …

# Realisation / Realisierung

In the chapter Realisation the „how“ is described, how the project is realised. The source code of the implementation should not be printed into this chapter. It is possible to use and describe relevant code snippets (font Courier New) and self-created flow diagrams, sequence diagrams or similar.

Im Kapitel Realisierung wird das „Wie“ beschrieben, wie wird das Projekt umgesetzt. Die einzelnen Schritte zur Realisierung des Ziels werden erläutert. In der Realisierung wird kein Quellcode abgedruckt, es können aber einzelne relevante Code-Schnipsel (Schrifttyp Courier New) und selbsterstellte Fluss-, Sequenzdiagramme oder ähnliches verwendet werden.

# Summary and Perspectives / Zusammenfassung und Ausblick

New Ideas / Neue Ideen

To take the discussion further / Die Diskussion weiterführen

Criticism of one´s own work / Kritik an der eigenen Arbeit

* Why it went wrong? / Warum ging es schief?

Example / Beispiel:

The developed prototype confirmed the concept of the software for exchanging files between server and client computers. File and user management on the server has been solved with a MySQL database. The server component has a web interface. With this web interface, the server administrator can configure the server, can manage files and can manage the authorized user. The client computer uses a graphical user interface that enables the user to log on to the server and upload and download files. To transfer the files between the computers, file transfer protocol (FTP) was used.

Multiple users can simultaneously log on to the server component. Each user only sees the files uploaded by him. Each user must be authenticated with his user name and password in order to get access to his files.

The architecture can be extended with an option for a simultaneous upload of multiple files in order to exploit the available bandwidth optimally. In order to exchange files also between server and smartphone, a corresponding smartphone app should be created as a supplement for the client component.

…

Der im Rahmen dieser Thesis entwickelte Prototyp bestätigt das hier vorgelegte Konzept für eine Software zum Austausch von Dateien zwischen Server- und Clientcomputer. Die Datei- und Benutzerverwaltung auf dem Server wurde mit einer MySQL-Datenbank gelöst. Die Serverkomponente besitzt ein Webinterface, mit dem der Serveradministrator den Server konfigurieren bzw. Dateien und die berechtigten Benutzer verwalten kann. Der Clientcomputer besitzt eine grafische Benutzeroberfläche, mit der die Benutzer sich am Server einloggen und Dateien hoch- bzw. herunterladen können. Als Dateiübertragungsprotokoll wurde das File Transfer Protokoll (FTP) benutzt.

An der Serverkomponente können sich mehrere Benutzer gleichzeitig anmelden. Jeder Benutzer sieht nur die von ihm hochgeladenen Dateien. Jeder Benutzer muss sich mit seinem Usernamen und Passwort authentifizieren, um Zugriff auf seine Dateien zu bekommen.

Erweitert werden kann diese Architektur mit einer Option zum gleichzeitigen Hochladen von mehreren Dateien, um die zur Verfügung stehende Bandbreite optimal ausnutzen zu können. Damit die Dateien auch zwischen Server und Smartphone ausgetauscht werden können, sollte als Ergänzung für die Clientkomponente auch eine entsprechende Smartphone-App erstellt werden.

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# Abbreviations / Abkürzungen

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**3**

3GPP Third Generation Partnership Project

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**A**

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**G**

GSM Global System for Mobile communications

GUI Graphical User Interface

GW Gateway

**H**

HSS Home Subscriber Server

HTML Hypertext Mark-up Language

HTTP Hypertext Transfer Protocol

…

**Z**

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# References / Referenzen

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# Appendix / Anhang

Attached CD/DVD content / Inhalt der CD/DVD