TECHNISCHE HOCHSCHULE NÜRNBERG
GEORG SIMON OHM

Faculty of Computer Science

IT-based text generation using NLP methods

State of the art and design of a prototype

Bachelor Thesis in
Business Information Systems and Management

by

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Hinweis: Diese Erklärung ist in alle Exemplare der Abschlussarbeit fest einzubinden. (Keine Spiralbindung)

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Preface I

The following thesis was created during the seventh and last semester at the Georg Simon Ohm University of Applied Science. Within the last three semesters, I realized that my major interest among all IT related topics is artificial intelligence.

My personal interest started basically with a group IT-project, in which my team and I programmed an autonomously driving remote control car with a deep neural network together with a Raspberry Pi 3B+. From this first project on, I selected all my further elective courses to be related to machine learning or data science in any possible way. I wanted to increase my knowledge further, so I searched for a website that provides courses related to AI. I found *www.udacity.com*, which offers courses in cooperation with top IT companies, such as Google, Airbnb, or Microsoft. Out of curiosity, I bought the course *Natural Language Processing.* After successfully finishing it, I was encouraged to write my bachelor thesis in a *Natural Language Processing* related topic. Together with my professor *Prof. Dr. Alfred Holl*, I worked out a structured methodological table for the entire structure of this paper. Even though Natural Language Processing is just a subfield of machine learning, the current state-of-the-art research is far beyond what I can research within a bachelor thesis. I decided to write my thesis about the subfield *textgeneration* within NLP. My state-of-the-art research includes all *hot topics* within NLP, and my prototype focuses only on the text generation part, to dive deeper into what NLP and especially text generation can accomplish in the year 2020.

Preface II

For my research, I encountered a lot of old and recently published papers, mostly from *https://arxiv.org/*. To read through the papers requires a lot of prior knowledge, especially in mathematics, which I learned during my semester in Hong Kong at the City University of Hong Kong. To fully understand the mathematics given in this thesis, enhanced knowledge of calculus and linear algebra is required. Even if this is not the case, I will describe the process in such a way that it can be comprehended without looking at the maths.
Machine Learning and, more specifically, NLP is not an intuitive study. I provided for the matrix notations the common terminologies originated from top researchers and tried to make the entry into this field as smooth as possible if the reader has no prior knowledge about this topic. During the five-month development process of the bachelor thesis, I gained much knowledge. I recognized that NLP is a huge topic, constantly under research. To keep up to date with the latest publications requires much effort.
To give a full state-of-the-art review about *all* NLP related disciplines is not possible within this thesis. For this reason, I focus entirely on the development of the *Neural Text Generation* (NTP), which includes more fields than the reader might imagine.

	Titel / Kapitel		Untertitel / Unterkapitel	——Woher?——		——Wie?——	——Was?——
				Wissensinput	Frageinput	Methode	Zielbeschreibung
0	**IT-basierte Textgenerierung mit Hilfe von NLP-Methoden** State of the Art & Entwurf eines Prototypen			Allgemeingültig: • Fachbücher, Bücher • HongKong, TH-OHM • Online Kurse	1. Was ist der State of Art von NLP - Systemen. 2. In welcher Qualität kann ich den Textgenerierungs- Prototypen selbst programmieren und welche Güte hat dieser?	1. Darstellung des State of the Art der NLP-Systeme. 2. Studium der relevanten Aspekte des NLP und Programmierung eines IT-basierten Textgenerierungs-Prototypen.	1. State of the Art fachlich herausarbeiten. 2. Einen Prototypischen Algorithmus programmieren, der zu einem gegeben Input z.B. ein Buch immer wieder neue kreative Fortsetzungen generiert.
1	Einleitung	1.1	Fallbeispiel eines aktuellen NLP-Systems	• [0.1] • Wissenschaftliches Schreiben und	1. Was sind aktuelle, nützliche Einsatzgebiete von NLP-Textverarbeitungs-Systemen? 2. Was ist der Nutzen meines NLP-Prototypen im Bereich der Textverarbeitung?	1. Recherche über die aktuellen und geplanten NLP-Systeme, im Bereich der Textverarbeitung. 2. Vorstellung meines Beitrags zu NLP-Systemen mithilfe meines Prototyps.	1. Antwort auf die Frage, warum meine Bachelorarbeit sinnvoll ist und welche Motivation ich habe zur Bearbeitung 2. Erläuterung durch einen interessanten leichten Einstieg.
2	State of the Art	2.1	Relevante Aspekte der Mathematik	[1.1]	Welches mathematische „know-how“ ist notwendig, um NLP-Systeme für Textverarbeitung und meinen Prototypen technisch verstehen zu können?	Recherche nach den relevanten Aspekten der Mathematik für dieses Thema.	Beschreibung der anwendungsbezogenen mathematischen Modelle für diesen Themenkomplex anhand von Formeln und Erklärungen.
		2.2	Geschichte des NLP	• [0] • [0.1]	1. Seit wann wird an NLP-Systemen geforscht? 2. Ab welchem Punkt konnte man effektiven Nutzen aus diesen Systemen ziehen?	1. Literaturrecherche über die Geschichte des NLP (40 Jahre). 2. Literaturrecherche über die ersten Einsätze der NLP-Systeme.	1. Darstellung der Geschichte des NLP in Form einer zeitlichen Abfolge. 2. Nutzen der ersten NLP-Prototypen oder Technologien die im Einsatz waren.
		2.3	Aktuelle Trends der Technologie	• [0] • [0.1] • [2.2] • Fallbeispiele	1. Was sind aktuelle NLP-Systeme imstande zu leisten? 2. Wo sind die Einsatzgebiete?	1. Literaturrecherche über aktuelle Trends (+ - 5 Jahre). 2. Recherche von aktuelle Papern und Veröffentlichungen.	1. Darstellung der aktuellen Technologien. 2. Blick in die kurzfristige Zukunft anhand von aktuellen Fallbeispielen und Forschungsergebnissen.
3	Prototyp	3.1	Zielsetzung / Anforderungen	• [0] • [1] • [2]	1. Was soll mein Prototyp mit gegebenen Mitteln leisten können? 2. Welcher Output ist im besten Fall zu erwarten?	1. Requirements Engineering. 2. Klassifizierung und Analyse möglicher Ergebnisse, z.B. ob der Output grammatikalisch korrekt ist.	1. Erläuterung des Umfangs meines Prototyps. 2. Sammlung und Klassifizierung der Anforderungen an den Algorithmus und dessen Output.
		3.2	Fachkonzept	[3]	1. Wie ist mein Prototyp strukturiert? 2. Welche Algorithmen verwende ich? 3. Welche Prozesse durchlaufen die zu verarbeitenden Daten? 4. Wie werden die Daten verarbeitet?	1. Erstellen eines Fachkonzepts 2. Algorithmus modellieren 3. Prozessmodellierung 4. Datenflussmodellierung und, oder Datenmodellierung	1. Fachkonzept fertig erstellt. 2. Der Prototyp wird ohne IT Bezug anhand von verschiedenen Teilmodellen modelliert. 3. Die einzelnen Prozesse werden ohne konkreten Implememtierungs-Vorschlag modelliert. 4. Datenverarbeitung visualisiert
		3.3	Implementierung	[3.3]	1. Welche Technologien verwende ich für meinen Prototypen: - „Welche Python Bibliotheken und IDE?“ - „Welche HW & SW-Anforderungen gibt es?“ 2. Welche Probleme traten bei der Programmierung auf?	1. Software-Abhängigkeits-Portfolio erstellen - Vergleich geeigneter Programmiersprachen - Recherche der erforderlichen Bibliotheken - Recherche der erforderlichen Hardware, Software und Auswahl 2. Software entwickeln - Fehler reporten an Hersteller, Bib, etc.	1. Erstellung eines IT-Konzepts in Form einer Beschreibung der notwendigen technischen Mittel anhand von Teilmodellen 2. Problemstellungen erklären und das Auftreten eines Problems „reverse Engineeren“
		3.4	Evaluation	[3.4]	1. Wie ist der Output des Prototyps zu bewerten? 2. Wie bewertet man die Qualität des Outputs? 3. Was kann verbessert werden?	1. Soll-Ist-Vergleich der Anforderungen mit dem Output des Prototypen. 2. Vergleich mit verwandten Arbeiten. 3. Recherche über potentielle Verbesserungen des Algorithmus.	1. Evaluation und Analyse des Ergebnisses anhand von grammatikalischer Richtigkeit und Sinn. 2. Bessere Ergebnisse mit meinen vergleichen. 3. Optimierungsmöglichkeiten für meinen Prototypen evaluieren.
4	Generierung von übertragbarem Wissen			[0] bis [3]	Um welche Elemente könnte mein Projekt modular Erweitert werden um ein Anderes oder Besseres Ergebnis zu erzeugen und welchen Einfluss könnte es auf die Forschung haben?	Verallgemeinerung aus den bisher erarbeiteten Ergebnissen.	Einordnung der Evaluationsergebnisse in einen gesellschaftlichen Kontext.

Abstract

– At the end , finally finished :) –

Contents

Chapter 1.

Introduction

1.1. Structure of the thesis

The aim of my thesis is to survey the current state of the art in text generation, especially on the focus of text summarization. For readers who are not familiar with machine learning in general, I will provide a zoom-in introduction into text summarization. My approach is feed-forward from the definition of machine learning, into the natural language processing field, further into the text generation field and within that, I focus on the text summarization part in chapter 1 - Introduction. When research and state of the art results in some natural language processing fields are achieved, those results can often be used across other disciplines as well. For this reason, I provide the most crucial text generation historical achievements in combination with the latest text summarization results, because both topics intersect in many aspects. The crucial concept of historical and modern approaches to summarize and generate text are introduced in chapter 2 - State of the Art. To illustrate the basic workflow of a text summarizing system, I programmed a prototype. The concept, development and evaluation of this summarizer are located in chapter 4 - Prototype, but it requires prior knowledge to fully understand the mechanism from the input to the output. Finally in the last chapter I will discuss further improvements for my prototype and a brief discussing into the future of text generation.

1.2. Machine Learning

In the last decade, Machine Learning (ML) is increasingly finding its way into businesses and society. Many websites and businesses use Machine Learning techniques to improve the user and costumer experience. The phrase *Machine Learning* was originally introduced in 1952 by Arthur Samuel. He developed a computer program for playing the game checkers in the 1950s. Samuel's model was based on a model of brain cell interaction by Donald Hebb from his book called *The Organization of Behavior* published in 1949. Hebb's book introduces theories on neuron excitement and the neural communication. Figure 1.1 illustrates the

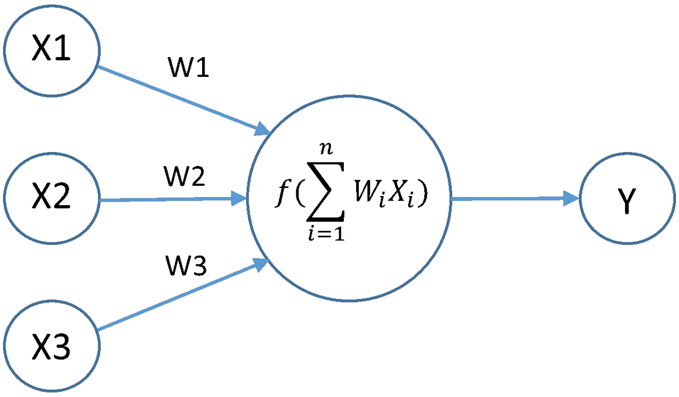

Figure 1.1.: A simple Neuron with 3 inputs and 1 output [Sing 17]

model of the brain cell. Nowadays, this brain neuron based model is mostly declared to be not realistic enough [Andrew Ng, deeplearning.ai], because the structure of a neuron in the brain is far more complex than the illustration in figure 1.1 suggests. Nevertheless, it provides a really good entry point for this research field.

The roots of Neural Networks (NN) lie down almost 80 years ago in 1943 when **McCulloch-Pitts** [McCu 43] compared for the first time neuronal networks with the structure of the human brain. The range in which Neural Networks (in the year 2020) apply to modern technologies is wide. Some disciplines have only been created due to the invention of Neural Networks, because they solve existing and new problems very effectively and efficiently. Many frequently held conferences around the globe proof continuous evidence of the successes of Neural Networks. Among those various disciplines counts for example *Pattern recognition* with Convolutional Neural Networks (CNN) [Yann 98] for example to predict the classes of images with the famous *CIFAR-10* dataset [Kriz]. Many amateurs [Löh 19] and experts annually attempt to show their latest results in beating the former best accuracy.

Convolutional Neural Networks is just one of many other Neural Network building blocks, because a modern network consists of many different layers. Natural Language Processing is one of the various sub fields of Machine Learning. Strictly speaking, it is actually a multidisciplinary field consisting of Artificial Intelligence (AI) and computational linguistics. Natural Language Processing is dedicated to understand and process the interactions between human (natural) language and computers. Natural Language Processing is a very broad term and can apply many different tasks, such as:

- Sentiment Analysis
- Machine Translation
- Speech Recognition

- Text Generation (Neural Text Generation *NTG*)
- Chat Bots

All of this tasks require many steps to function properly. In the broadest sense, there is always an Input and an Output, which are shown in Table 1.1.

Components of NLP methods			
	Speech	Text	Images
Input Analysis	Speech Recognition	Natural Language Processing methods	Image Recognition
Output Synthesis	Generation of Speech	Generation of Text	Generation of Images

Table 1.1.: A closer look into the NLP disciplines

It shows that the text generation is often the output part of a Natural Language Processing model. Data is collected through various different sources, e.g. images, videos or speech, then it is further processed and generates the desired output. Useful examples are shown in Table 1.2.

Examples of NLP methods			
	Speech	Text	Images
Input Analysis	Siri listens	Read in document	Image of a face
Output Synthesis	Siri answers	Generate Summary	Face detected

Table 1.2.: Examples for three different NLP tasks

For this Bachelor thesis, the focus is on the output part of a Natural Language Processing system, which inputs text as shown in Table 1.1 and 1.2. Text generation is therefore in general the output part of an input-output NLP system.

Another term for text generation is *Language Modelling*, because text generators use the words of a language and grammar as input for the model. In the past five years, primarly two approaches were used for modelling a Natural Language Processing system, namely the **rule-based** system and the **template-based** system (Figure 1.2) [Xie 17]. Today neural end-to-end systems are *state-of-the-art* [Jeka 17]. These systems offer more flexibility and scale with proportionately better results, and less data is required because of the increased

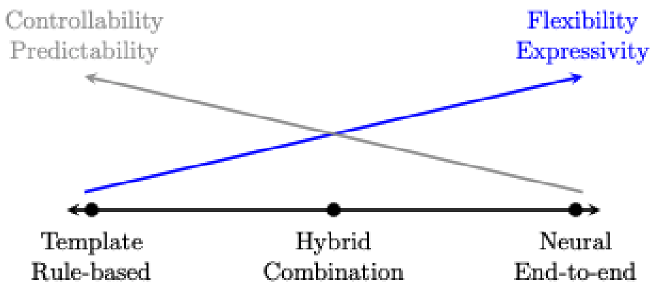

Figure 1.2.: Rule-Based vs. Neural-Text-Generations System [Xie 17], Page 4

complexity. A major disadvantage is that the necessary computing power has increased exponentially. However, this leads to a complex problem because it becomes more and more challenging to understand the decisions of the neural network. The neural network is still, to a large extent, a *black box*. Especially in NLP it gives surprisingly good results. The neural network models for text processing are difficult to understand, so nowadays, compromises between rule-based systems still have to be made, and hybrid systems are most commonly in use.

When Neural end-to-end systems are used, text generation is often referred as Neural Text Generation (NTG). More examples for Neural Text Generators as output synthetical component are:

- Speech recording and conversion to text
- Conversation systems e.g. chatbots
- Text summary
- Caption generation

In order to train language models properly, Deep Learning (DL) algorithms teach the model the probabilities of occurring words with respect to the preceding words. There are several approaches to achieve this goal. Language models can be trained on the level of words, whole sentences, or even whole paragraphs. The granularity in which the training takes place is called *n-grams*, where n represents the number of preceding words. Further explanation in Section **??** of Chapter 2. Deep Learning will be explained in necessary depth in Section 2.2.

1.3. Case study of a Text Summarization System

Chapter 2.

State of the Art

2.1. Background and Theory

2.1.1. Prerequisites

2.1.2. Encoder

2.1.3. Decoder

2.2. History of Text Generation

nlg-survey-long

2.2.1. Text Generation Tasks

raditionally, the nlg problem of converting input data into output text was addressed by splitting it up into a number of subproblems. The following six are frequently found in many nlg systems (Reiter and Dale, 1997, 2000); their role is illustrated in Figure 1:

- Content determination: Deciding which information to include in the text under construction
- Text structuring: Determining in which order information will be pre- sented in the text
- Sentence aggregation: Deciding which information to present in individual sentences
- Lexicalisation: Finding the right words and phrases to express informa- tion
- Referring expression generation: Selecting the words and phrases to iden- tify domain objects
- Linguistic realisation: Combining all words and phrases into well-formed sentences

2.2.2. Architectures and Approaches

nlg-survey-long Kapitel 3

- Rule-based, modular approaches
- Planning-based approaches
- Data-driven approaches

2.2.3. Neural Text Generation

NTG with Supervised Learning NTG with Reinforcement Learning NTG with GAN's

2.3. Current Trends in Text Summarization Technology

2.3.1. Summarization Factors

Single Doc - Multi Doc Input Factors Purpose Factors output factors neural-text-summary

2.3.2. Extractive

2.3.3. Abstractive

2.3.4. Combinational Approach

2.3.5. Reinforcement Learning

2.3.6. Evaluation

ROGUE

Chapter 3.

Prototype

```
x = 1
if x == 1:
    # indented four spaces
    print("x␣is␣1.")
```

Listing 3.1: This is an example of inline listing

You can also include listings from a file directly:

```
x = 1
if x == 1:
    # indented four spaces
    print("x␣is␣1.")
```

Listing 3.2: This is an example of included listing

3.1. Objective

Textsummarization

3.2. Technical concept

Fachkonzept - Proto

3.2.1. Structure

The different steps of Text Generation

- Importing Dependencies
- Loading the Data
- Creating Character/Word mappings
- Data Preprocessing
- Modelling
- Generating text

3.2.2. Neuronal Net

LSTM

RNN

Experimenting with different models

- A more trained model
- A deeper model
- A wider model
- A gigantic model

3.2.3. Process Modeling

Funktionen etc.

3.2.4. Data flow modelling

Diagramm

3.3. Implementation

Code for the Machine Translating

3.4. Evaluation

Print Ergebnisse

Bild

Image Caption

Chapter 4.

Generation of transferable knowledge

Modular expandability of my project. Classification in social context

Appendix A.

Supplemental Information

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