

The Impact of Deep Learning on Speech Synthesis with Embedded or Mobile Devices

Hannes Bohnengel

Technical University of Munich
hannes.bohnengel@tum.de

ABSTRACT

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KEYWORDS

Deep Learning, Deep Neural Network, Embedded System, Mobile Device, Speech Synthesis, Text-to-Speech

1 INTRODUCTION

Virtual personal assistants (VPA) like Siri, Cortana or Google Now start having a huge impact on the way of interacting with electronic devices like smartphones or notebooks. Up to now the VPAs help only with rather simple tasks like search queries, starting phone calls or setting a clock, but according to a recent survey from the IT research firm Gartner [1], this will change in the near future. With the Facebook Messenger it is already possible to make purchases or to order an Uber car and new use cases are expected soon. The survey also states, that through the vast increase of devices in the scope of the Internet of Things (IoT) the way of interacting with machines will go towards minimal or zero touch. Instead of interacting through common touch-displays or buttons, the user simply speaks to the device, like to another person. To enable this, both Automatic Speech Recognition (ASR) and speech synthesis are essential technologies.

In this paper I will only focus on the speech synthesis part. A widely spread technique to synthesize human speech from a given text or from linguistic descriptions is Statistical Parametric Speech Synthesis (SPSS); also referred to as Statistical Parametric Speech Generation (SPSG) [5]. This technique is based on the usage of Hidden Markov Models (HMMs). Zen *et al.* [9] show that it has several advantages over its predecessor, the concatenative speech synthesis, for example the flexibility in changing voice characteristics and a smaller memory footprint. However the quality of the generated speech still has potential for improvement. Due to over-smoothing the voice sounds muffled in comparison to natural speech.

This is where recent achievements in deep learning come in. Deep learning is usually referred to as a class of machine learning techniques that achieve tasks like feature extraction or pattern analysis by using many connected layers of non-linear information processing [3, 5]. Since 2006 advances in the training algorithms of Deep Neural Networks (DNNs) have enabled the field of

deep learning applications to emerge [2]. Most machine learning models until then had used shallow structures, like for example HMMs, Gaussian Mixture Models (GMMs), Conditional Random Fields (CRFs) or Support Vector Machines (SVMs). In these structures only one layer is responsible for generating features out of the raw input signals. While achieving quite good results with rather simple problems, they reach their limit when it comes to more complex tasks like processing human language or natural images [3]. In the tutorial survey [3] the author also states four different approaches to improve speech synthesis through deep learning models, whereof three are dealing with SPSS. One of those three approaches is described in [8], where the authors implemented a part of the speech synthesis system by using a DNN and observed an improved performance in predicting output features. In [4] a more general approach is conducted by investigating what effects the deployment of a DNN on different parts of the SPSS system has. An improvement of the naturalness of the generated speech was one of the main results.

For implementing speech synthesis on resource-constrained devices like smartphones or tablets, SPSS is considered the best solution due to the tradeoff between voice quality and acceptable footprint size [7]. Since the computational costs of SPSS are often high, some optimization steps like applying fewer conditional calls are conducted in [7] to make the HMM-based speech synthesis technique SPSS more suitable for mobile devices. Going one step further, in [2] an approach to adapt SPSS for embedded devices by using a deep learning model, an Auto Encoder (AE), is employed. Four tasks (syllabification, phonetic transcription, part-of-speech tagging and lexical stress prediction) are examined and tested with the use of this deep learning model. As results the authors highlight highly reduced model sizes, higher training times, very close performance and a similar run time in comparison to the state-of-the-art models. This shows that the usage of deep learning models for speech synthesis on embedded systems is a reasonable step, not only to improve performance and voice quality, but also towards the independability on online databases for speech synthesis.

The remaining paper is structured as follows: Section 2 first states the motivation, why speech synthesis is a useful technology. Then it describes the conventional approach without deep learning models for speech synthesis and gives an overview of advantages and drawbacks of the used models and techniques. This is followed by a brief explanation of the probably most common used technique SPSS, where the paper [9] has been chosen as commonly cited reference. Thereafter two possibilities how SPSS can be improved by deploying deep learning models are characterized, wherefore the papers [4, 8] are reviewed. In Section 4 the motivation, why speech synthesis is important on embedded or mobile devices is given, followed by two examples on how speech synthesis can be implemented on an embedded system, once without [7] and once with deep learning models [2]. Finally Section 5 summarizes the essential points of this paper and gives some future directions.

2 CONVENTIONAL SPEECH SYNTHESIS

2.1 Motivation & Approaches

Something about applications!

The classic applications of speech synthesis according to [Cam-Seminar] are the following

Accessibility, screenreader
Telephone services, dialogue systems
Basic (and rather boring) e-Book reader
In-car navigation
Basic voice communication aids for people with disabilities

- virtual personal assistants
- reading aid for visually impaired
- Stephen Hawking
- public announcements (train stations)
- navigation / media systems in cars (handsfree)
- man-machine-interface

See here: [6], *New and emerging applications of speech synthesis*,
<http://www.gingersoftware.com/content/blog/text-to-speech-online/>,
<http://www.readspeaker.com/benefits-of-text-to-speech/>

According to [?] speech synthesis can be divided into three types: Canned speech, Context-to-Speech (CTS) and Text-to-Speech (TTS). Canned speech more or less is the replay of prerecorded spoken sentences or words with none or very little adjustments. A typical example are the announcements on train stations. Because of the high effort of recording everything (almost) exactly as it is replayed this approach is limited to only a few simple applications. With CTS the waveform is generated out of a linguistic description without any information of the respective text. In this way no natural language processing is required, but nevertheless CTS nowadays has not made any important impact. The last and most promising type is TTS.

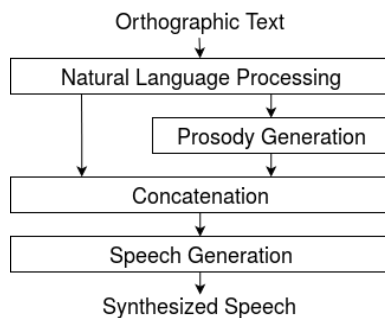


Figure 1: General structure of a TTS-system [?]

Brief overview of conventional approaches how to implement speech synthesis, with highlighting advantages and drawbacks.

- concatenative & unit-selection
 - formant-based
 - diphone-based
 - SPSS
 - etc. ??
-
- Why speech synthesis is useful/important?
What are use cases in daily life?
 - Why there is need to further improve this technology?

2.2 HMM based Speech Synthesis: SPSS

Description of one approach (SPSS) more in detail [9].

3 SPSS WITH DEEP LEARNING MODELS

Description of the improvements of the approach in previous subsection by using deep learning models.

3.1 General ways for improvement

The effect of neural networks in statistical parametric speech synthesis [4]

3.2 One specific approach for improvement

Statistical parametric speech synthesis using deep neural networks [8]

4 SPEECH SYNTHESIS ON EMBEDDED DEVICES

4.1 Motivation

Why is it important to implement speech synthesis on embedded platform?

What needs to be thought about when dealing with embedded or mobile devices?

4.2 HMM-based Approach

An example of how speech synthesis can be implemented on embedded platform without deep learning (core paper 3).

4.3 Deep Learning-based Approach

An example of how speech synthesis can be implemented on embedded platform WITH deep learning (core paper 4).

5 CONCLUSIONS

Here the core points will be repeated and concluded.

Some future aspects will be highlighted. What should be done in the future? See CamSpeechSynthesis-Seminar:

- Voice cloning
- Voice reconstruction
- Personalised speech-to-speech translation
- Articulatory-controllable speech synthesis

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• Section 1	1.25	(incl. Abstract)
• Section 2.1	0.75	
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Questions:

- (1) Why speech synthesis is important? What are its applications?
- (2) What are the conventional techniques of speech synthesis? What are the drawbacks of such techniques?
- (3) What is deep learning? What improvements do deep learning algorithms bring?
- (4) How some algorithms are modified to suit speech synthesis?
- (5) Why is it important to implement speech synthesis on embedded platform?
- (6) An example of how speech synthesis can be implemented on embedded platform without deep learning.
- (7) How the 3 can be combined?
- (8) Future works.