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Automatic speech recognition in physics teacher education

Master's Thesis in Information Technology

September 3, 2019

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Title: Automatic speech recognition in physics teacher education

Työn nimi: Automaattinen puheentunnistus fysiikan opettajakoulutuksessa

Project: Master's Thesis

Study line: Educational Technology

Page count: 13+0

Abstract: TODO: Abstract

Keywords: TODO: Keywords

Suomenkielinen tiivistelmä: TODO: Tiivistelmä

Avainsanat: TODO: Avainsanat

Glossary

TODO

TODO: Glossary

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1 Introduction

Modern physics classroom instruction attempts to improve learning by reducing the cognitive load, which is done by providing a clear organizational structure for the factual knowledge and linking new material to previously known ideas (Wieman and Perkins 2005). The goal of physics instruction is to help students become experts capable of solving problems (Fischer et al. 2014; Wieman and Perkins 2005). While lecture based instruction is often not very effective for retaining new knowledge (Wieman and Perkins 2005), the content structure and relationships between concepts presented by the teacher positively correlate with student learning gains when analysed with conceptual network analysis (Fischer et al. 2014).

For a long time automatic speech recognition (ASR) was outperformed by human speech recognition (HSR), but with the recent developments in the deep learning approach the error rate of automatic speech recognition and human speech recognition is almost the same in certain tasks (Spille, Kollmeier, and Meyer 2018). This however is language specific. Work on automatic speech recognition with conversational Finnish started in 2012 and word error rate of 27.1% was achieved by 2017 (Enarvi 2018).

In natural language processing the creation of treebanks such as Turku Dependency Treebank and FinnTreeBank in the past decade have allowed for development of natural language processing toolkits with adequate performance with Finnish language such as FinnPos (Silfverberg et al. 2016) and TurkuNLP (Kanerva et al. 2018). Lemmatization in the new toolkits is of particular interest, because it is essential for real world tasks in inflective languages such as Finnish (Kanerva et al. 2018).

Manually transcribing and preprocessing lessons from audio data for analysis is a very laborious task. The aim of this study is to develop a pipeline for studying physics lesson content structures and relationships between physics concepts with conceptual network analysis using automatic speech recognition and natural language processing. This is done to provide a new tool for analysing physics instruction for research and teacher education purposes.

2 Physics instruction quality

TODO: Paragraph about science education and physics education history TODO: Paragraph about the change of science and physics education and modern physics education TODO: Paragraph about educational material and pedagogical tools TODO: Paragraph about physics instruction

TODO: Paragraph about cognitive structure and content structure TODO: Paragraph about how cognitive structure fits with education (geeslin, shavelson) TODO: Paragraph about linking cognitive structure of students and teachers TODO: Paragraph about content structure with written text with content structure (geeslin, shavelson, wieman)

TODO: Paragraph about pedagogical link making

2.1 Pedagogical link making

TODO: (Scott, Mortimer, and Ametller 2011)

2.2 Conceptual network analysis

TODO: (vargas; McLinden 2013; Fischer et al. 2014)

3 Speech as data

TODO: AI overview, AI history, ASR and NLP concepts

3.1 Automatic speech recognition

Automatic speech recognition (ASR), sometimes called speech to text, is a classification task, where the goal is to predict what was said from the audio signal of speech. Early ASR systems had an acoustic model which detected different sounds also known as phonemes to recognize numbers, some vowels and consonants for a single speaker (Juang and Rabiner 2005). The later addition of a language model based on statistical grammar or syntax helped to predict the correct word based on what words previously appeared in the sentence (Juang and Rabiner 2005). Modern ASR systems utilize the fact that sentences are sequences of words and words are sequences of phonemes (Bengio and Heigold 2014). This is a difficult machine learning task because of a large search space, large vocabulary, undetermined length of word sequences and problems related to aligning speech signal to the text (Enarvi 2018).

Speech is highly variable even with a single speaker due to noise, but different pronunciations and accents mean that the audio signal will be different despite the same words being spoken (Juang and Rabiner 2005).

3.1.1 Finnish speech data

TODO: Conversational vs official Finnish

3.2 Natural language processing

TODO: NLP overview (Silfverberg et al. 2016; Kanerva et al. 2018)

3.2.1 Word embedding

TODO: word2vec

3.2.2 Lemmatization and stemming

TODO: Snowball vs TurkuNLP lemmatization

3.2.3 Finnish NLP data

TODO: Data from different sources, treebanks for parsing vs. word lists/text

4 Methods

4.1 Data

TODO: (Fischer et al. 2014)

4.2 Automatic speech recognition

TODO: (Enarvi 2018)

4.3 Lemmatization and stemming

TODO: TurkuNLP (Kanerva et al. 2018) TODO: libvoikko <https://github.com/voikko/corevoikko/tree/main>

TODO: FinnPOS (Silfverberg et al. 2016)

4.4 Word frequency

4.5 Network analysis

Social network analysis has been used in physics education research for example to study student collaboration (Vargas et al. 2018), interactions within student communities (Brewer, Kramer, and Sawtelle 2012)

5 Results

TODO:

6 Conclusions

TODO:

Research is being done in collaboration with the Department of Teacher Education at University of Jyväskylä and Centro de Investigación Avanzada en Educación (CIAE) at University of Chile.

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