

Deep learning for automatic speech recognition

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Associate professor in **speech and language processing**

Background from machine learning algorithms and pattern recognition systems

PhD 1997 at TKK on **speech recognition with neural networks**

Research experience in several top speech groups:

- Research Centers: IDIAP (CH), SRI (USA), ICSI (USA)
- Universities: Edinburgh, Cambridge, Colorado, Nagoya

Head of Aalto **speech recognition research group** + several national and European speech and language projects

Research topics:

- Speech recognition, language modeling, speaker adaptation, speech synthesis, translation, information retrieval from audio and video

Contents of this talk

1. Applications of Automatic Speech Recognition (ASR)
2. Building an ASR system
3. ASR research topics, where deep learning helps
4. Deep neural networks (DNN) for acoustic models (AM)
5. Deep neural networks (DNN) for language models (LM)

Using automatic speech recognition (ASR)

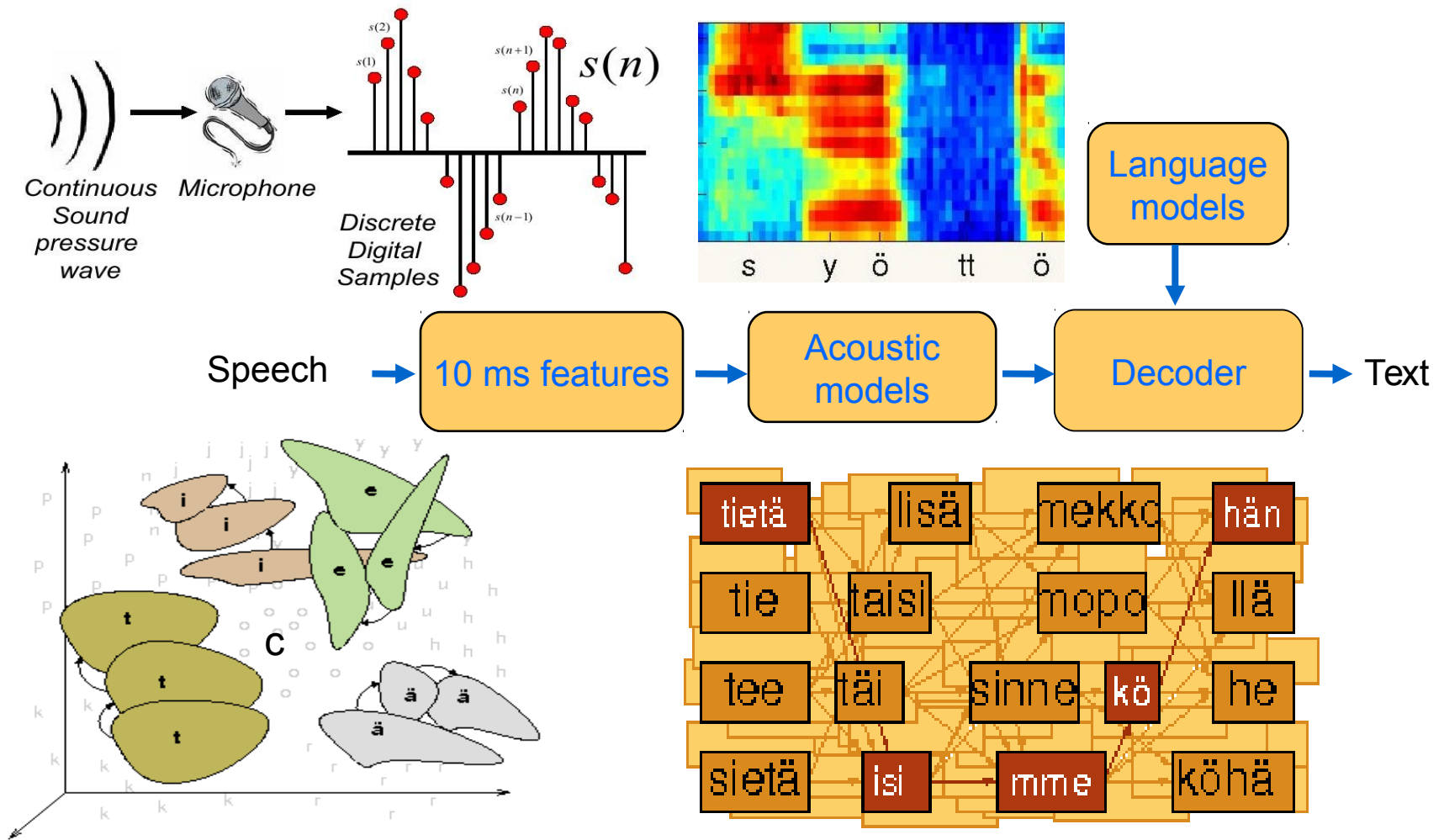


Mapping human speech to text or commands.

Has quickly become popular via voice search and virtual assistants in phones (Google, Siri etc).

Other applications: subtitling or indexing video recordings and streams, robots, toys, games, dictation, speech translation, disabled users, language learning and other education

In ASR systems, DNN can take various tasks



ASR performance depends on:

- Training and development data:
 - Quantity and suitability
- Recording and noise:
 - Microphone and distance
- Speakers and speaking styles:
 - Speaker changes
 - Clarity and style
- Language styles:
 - Grammatical vs colloquial
 - Planned vs spontaneous
 - Non-standard vocabulary



ASR research problems: requests for help

1. Deep learning for **acoustic** models
 - complicated density functions in time and frequency
 - variability between speakers
 - variability between styles
2. Deep learning for **language** models
 - syntax, semantics, pragmatics
 - long-range dependencies
 - spontaneous speech



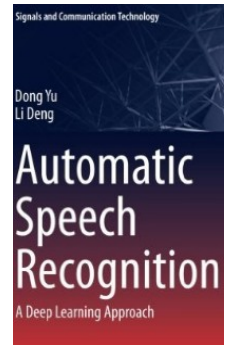
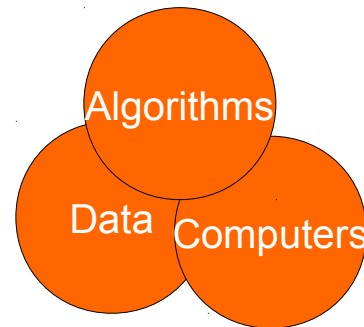
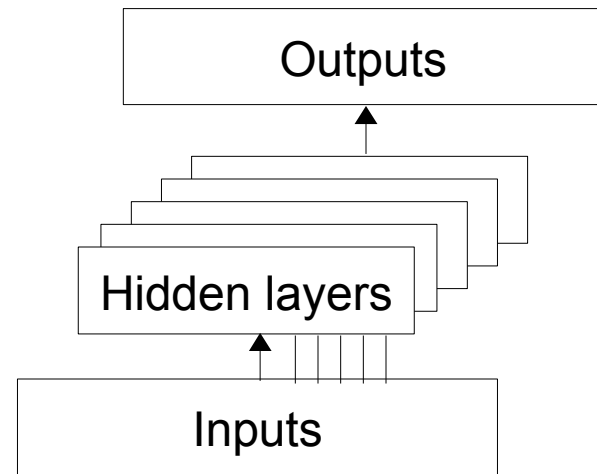
Deep learning in acoustic models (AM)

3 keys ideas in DNNs that improve ASR:

1. Processing in many hierarchical layers
2. Input from many frames
3. Output for context-dependent phones

Other significant improvements:

speedups, pre-training, sequence discriminative training, multitask learning, various NN architectures (CNN, RNN, LSTM, Highways)



See: D.Yu, L.Deng. Automatic Speech Recognition A Deep Learning Approach. Springer 2015.

Unsolved research problems for DNN AM

1. Adaptation into new situations with little data (1,2,5)
2. Far field microphones, noisy and reverberant conditions (3,4)
3. Accented and dialect speech (5,6)
4. Spontaneous, non-fluent, and emotional speech (1,6)

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- (1) M.Kurimo, S.Enarvi, O.Tilk, M.Varjokallio, A.Mansikkaniemi, T.Alumäe. Modeling under-resourced languages for speech recognition. Language Resources and Evaluation, pp.1—27, 2016.
 - (2) P.Smit, J.Leinonen, K.Jokinen, M.Kurimo. Automatic Speech Recognition for Northern Sámi with comparison to other Uralic Languages. Proc. IWCLUL 2016.
 - (3) H.Kallasjoki. Feature Enhancement and Uncertainty Estimation for Recognition of Noisy and Reverberant Speech. PhD thesis. Aalto University, 2016.
 - (4) U.Remes. Statistical Methods for Incomplete Speech Data. PhD thesis. Aalto University, 2016.
 - (5) P.Smit, M.Kurimo. Using stacked transformations for recognizing foreign accented speech. Proc. ICASSP 2011.
 - (6) R.Karhila, A.Rouhe, P.Smit, A.Mansikkaniemi, H.Kallio, E.Lindroos, R.Hildén, M.Vainio, M.Kurimo. Digitala: An augmented test and review process prototype for high-stakes spoken foreign language examination. In Show and Tell at Interspeech 2016 .

Deep learning in language models (LM)

Steps taken from conventional LMs to DNNs:

1. Smoothed and pruned N-gram LMs (e.g. modified Kneser-Ney, Varigrams) (1,2)
2. Continuous space models using N-gram features (e.g. Maximum Entropy LMs) (3,4)
3. Neural Network LMs with input on different time scales (e.g. Recurrent NNs, Long Short Term Memory) (5)

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- (1) V.Siivola, M.Creutz, M.Kurimo. Morfessor and VariKN machine learning tools for speech and language technology. Proc. Interspeech 2007.
 - (2) T.Hirsimäki, J.Pylkkönen, M.Kurimo. Importance of high-order n-gram models in morph-based speech recognition. IEEE Trans. on Audio, Speech and Language Processing, 17(4), 2009.
 - (3) V.Siivola, A.Honkela. A state-space method for language modeling. Proc. ASRU 2003.
 - (4) T.Alumäe, M.Kurimo. Domain adaptation of maximum entropy language models. Proc. ACL 2010.
 - (5) S.Enarvi, M.Kurimo. TheanoLM - An Extensible Toolkit for Neural Network Language Modeling. Proc. Interspeech 2016.
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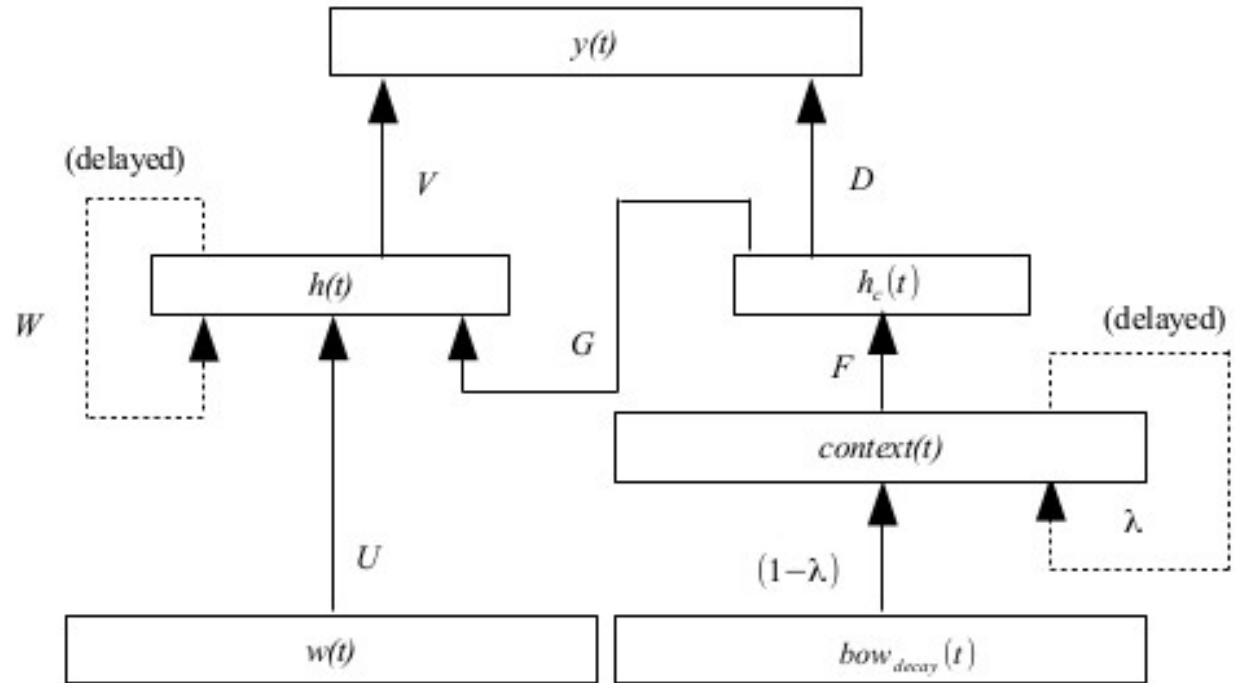
Research problems in DNN LM

1. INPUT & OUTPUT: What are the basic modeling units (words, morphemes, letters) and their most effective and scalable embeddings (1,2)
2. STRUCTURE: How to take into account both short-term (syntax, n-grams) and long-term (topics, references) dependences (3)

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- (1) M.Kurimo, S.Enarvi, O.Tilk, M.Varjokallio, A.Mansikkaniemi, T.Alumäe. Modeling under-resourced languages for speech recognition. Language Resources and Evaluation, 2016.
 - (2) M.Varjokallio, M.Kurimo, S.Virpioja. Class n-gram models for very large vocabulary speech recognition of Finnish and Estonian. Proc. SLSP 2016.
 - (3) A.Haidar, M.Kurimo. Recurrent Neural Network Language Model With Incremental Updated Context Information Generated Using Bag-of-Words Representation. Proc. Interspeech 2016.

An example of an extended RNN LM:

Here long context is used as a sliding bag of words (bow) via a small context layer. Improves models and saves parameters (WSJ task) (1).



- (1) A.Haidar, M.Kurimo. Recurrent Neural Network Language Model With Incremental Updated Context Information Generated Using Bag-of-Words Representation. Proc. Interspeech 2016.
- (2) S.Enarvi, M.Kurimo. TheanoLM - An Extensible Toolkit for Neural Network Language Modeling. Proc. Interspeech 2016.

Demoja puheentunnistuksesta

1. Puheen raakatranskriptio:

1. Eduskunnan täysistunto
2. TV-ohjelmat

2. Sanelut ja omat puheaineistot:

1. Offline puheentunnistuspalvelut: Kielipankki ja AaltoASR
<http://tinyurl.com/aaltoasr>
2. Online puheentunnistus: Laptop-versio

3. Puheesta puheeseen tulkkaukset:

1. Matkailufraasit (EMIME-demo)

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http://spa.aalto.fi/en/research/research_groups/speech_recognition/demos/

<http://tinyurl.com/aaltoasr>

Demos in YouTube:

https://www.youtube.com/channel/UCY4NOvOgKz9-x7rR_kkb51Q