Speech Processing with Linear and Neural Network Models

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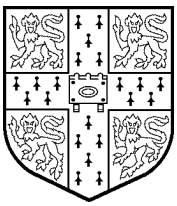

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Summary

This dissertation investigates some aspects of speech processing using linear models and single hidden layer neural networks. The study is divided into two parts which focus on speech modelling and speech classification respectively.

The first part of the dissertation examines linear and nonlinear vocal tract models for synthesising high quality speech with adjustable pitch. A source-filter framework for analysis and synthesis is used, in which the source is a representation of the glottal volume velocity waveform. Two families of linear model are considered, ARX (autoregressive with external input) and OE (output error). Their performance in estimating vocal tract transfer functions is compared on synthetic speech data, and the difference is explained in terms of the parameter estimation procedure, the frequency distribution of bias in the estimate and the assumptions about the spectrum of the noise in the vocal tract system. The noise spectrum for ARX models is shown to be perceptually significant for speech synthesis applications because it exploits auditory masking. Methods for improving poor quality syntheses from OE models are proposed. Nonlinear vocal tract models, implemented as feed-forward or recurrent neural networks, are investigated. Methods for initialising networks from linear models are developed. A modified recurrent architecture is introduced which permits initialisation from ARX models. The use of regularization, for imposing continuity between models of adjacent speech segments, and learning rate adaptation, for improving back-propagation training, are discussed. For synthesising real speech utterances, an audio tape demonstrates that ARX models produce the highest quality synthetic speech and that the quality is maintained when pitch modifications are applied.

The second part of the dissertation studies the operation of recurrent neural networks in classifying patterns of correlated feature vectors. Such patterns are typical of speech classification tasks. The operation of a hidden node with a recurrent connection is explained in terms of a decision boundary which changes position in feature space. The feedback is shown to delay switching from one class to another and to smooth output decisions for sequences of feature vectors from the same class. For networks trained with constant class targets, a sequence of feature vectors from the same class tends to drive the operation of hidden nodes into saturation. It is demonstrated that saturation defines limits on the position of the decision boundary resulting in context-sensitive and context-insensitive regions of the feature space. While saturation persists, it is shown that networks have reduced sensitivity to the order of presentation of feature vectors because movement of the decision boundary is inhibited. To improve this within-class sensitivity, training with ramp-like class targets is investigated. The operation of small recurrent networks is demonstrated for two tasks; classification of speech utterances into voiced and unvoiced segments, and classification of clockwise and anti-clockwise trajectories of vectors produced by two autoregressive processes.

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Dedication

To Mum and Dad. Thank you for supporting me in all the mad things I do.

Declaration

This 54,000 word dissertation is entirely the result of my own work and includes nothing which is the outcome of work done in collaboration.

Tina-Louise Burrows
Queens' College
March 20, 1996

Contents

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