Dynamic Programming Algorithms in Speech Recognition

Titus Felix FURTUNĂ
Academy of Economic Studies, Bucharest
titus@ase.ro

In a system of speech recognition containing words, the recognition requires the comparison between the entry signal of the word and the various words of the dictionary. The problem can be solved efficiently by a dynamic comparison algorithm whose goal is to put in optimal correspondence the temporal scales of the two words. An algorithm of this type is Dynamic Time Warping. This paper presents two alternatives for implementation of the algorithm designed for recognition of the isolated words.
Keywords: *dynamic programming, speech recognition, word detection.*

Introduction

Studies in speaking recognition field, as well as studies in other fields, follow two trends: fundamental research whose goal is to devise and test new methods, algorithms and concepts in a non–commercial manner and applied research whose goal is to improve existing methods, following specific criteria. This article deals with isolated words recognition within applied research trend.

The fundamental research aims at medium and especially long term benefits, while applied research aims at quick performances improvements of existing methods or extending their use in domains where they have less been used so far.

Improving performances in voice recognition can be done taking into account the following criteria:

- dimension of recognizable vocabulary;
- spontaneous ness degree of speaking to be recognized
- dependence/independence on the speaker;
- time to put in motion the system
- system accommodating time at new speakers;
- decision and recognition time;
- recognition rate (expressed by word or by sentence).

Today's vocal recognition systems are based on the general principles of forms" recognition [3][7]. The methods and algorithms that have been used so far can be divided into four large classes:

- Discriminant Analysis Methods based on Bayesian discrimination;

- Hidden Markov Models;
- Dynamic Programming –Dynamic Time Warping algorithm (DTW) [8];
- Neuronal Networks.

This article presents an example/alternative of dynamic programming DTW algorithm implementation in speech recognition.

1. Dynamic Time Warping Algorithm (DTW)

Dynamic Time Warping algorithm (DTW) [Sakoe , H. & S. Chiba-8] is an algorithm that calculates an optimal warping path between two time series. The algorithm calculates both warping path values between the two series and the distance between them.

Suppose we have two numerical sequences $(a_1, a_2, ..., a_n)$ and $(b_1, b_2, ..., b_m)$. As we can see, the length of the two sequences can be different. The algorithm starts with local distances calculation between the elements of the two sequences using different types of distances. The most frequent used method for distance calculation is the absolute distance between the values of the two elements (Euclidian distance). That results in a matrix of distances having n lines and m columns of general term:

$$d_{ij} = \left| a_i - b_j \right|, \ i = \overline{1,n}, \ j = \overline{1,m}.$$

Starting with local distances matrix, then the minimal distance matrix between sequences is determined using a dynamic programming algorithm and the following optimization criterion:

$$a_{ij} = d_{ij} + \min(a_{i-1,j-1}, a_{i-1,j}, a_{i,j-1}).$$

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Jinyu Li,Li Deng,Reinhold Haeb-Umbach,Yifan Gong

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    Readings in Speech Recognition Alexander Waibel,Kai-Fu Lee,1990-05 Speech recognition by machine a review D R Reddy The value of speech recognition systems W A Lea Digital representations of speech signals R W Schafer and L R Rabiner Comparison of parametric representations for monosyllabic word recognition in continuously spoken sentences S B Davis and P Mermelstein Vector quantization R M Gray A joint synchrony mean rate model of auditory speech processing S Seneff Isolated and connected word recognition theory and selected applications L R Rabiner and S E Levinson Minimum prediction residual principle applied to speech recognition F Itakura Dynamic programming algorithm optimization for spoken word recognition S Hakoe and S Chiba Speaker independent recognition of isolated words using clustering techniques L R Rabiner and others Two level DP matching a dynamic programming based pattern matching algorithm for connected word recognition H Sakoe The use of a one stage dynamic pr   *Speech Recognition* Claudio Becchetti,Lucio Prina Ricotti,1999-05-04 The capabilities of Automatic Speech Recognition are expanding quickly and this practical book helps engineers take advantage of the technology immediately featuring C code for implementing ASR algorithms a process for creating an interface quickly and methods for testing and developing new systems   **Automatic Speech and Speaker Recognition** Chin-Hui Lee,Frank K. Soong,Kuldip K. Paliwal,2012-12-06 Research in the field of automatic speech and speaker recognition has made a number of significant advances in the last two decades influenced by advances in signal processing algorithms architectures and hardware These advances include the adoption of a statistical pattern recognition paradigm the use of the hidden Markov modeling framework to characterize both the spectral and the temporal variations in the speech signal the use of a large set of speech utterance examples from a large population of speakers to train the hidden Markov models of some fundamental speech units the organization of speech and language knowledge sources into a structural finite state network and the use of dynamic programming based heuristic search methods to find the best word sequence in the lexical network corresponding to the spoken utterance Automatic Speech and Speaker Recognition Advanced Topics groups together in a single volume a number of important topics on speech and speaker recognition topics which are of fundamental importance but not yet covered in detail in existing textbooks Although no explicit partition is given the book is divided into five parts Chapters 1 2 are devoted to technology overviews Chapters 3 12 discuss acoustic modeling of fundamental speech units and lexical modeling of words and pronunciations Chapters 13 15 address the issues related to flexibility and robustness Chapter 16 18 concern the theoretical and practical issues of search Chapters 19 20 give two examples of algorithm and implementational aspects for recognition system realization Audience A reference book for speech researchers and graduate students interested in pursuing potential research on the topic May also be used as a text for advanced courses on the subject   *Advanced Algorithms and Architectures for Speech Understanding* Giancarlo Pirani,2013-11-09 This book is intended to give an overview of the major results achieved in the field of natural speech

understanding inside ESPRIT Project P 26 Advanced Algorithms and Architectures for Speech and Image Processing The project began as a Pilot Project in the early stage of Phase 1 of the ESPRIT Program launched by the Commission of the European Communities After one year in the light of the preliminary results that were obtained it was confirmed for its 5 year duration Even though the activities were carried out for both speech and image understand ing we preferred to focus the treatment of the book on the first area which crystallized mainly around the CSELT team with the valuable cooperation of AEG Thomson CSF and Politecnico di Torino Due to the work of the five years of the project the Consortium was able to develop an actual and complete understanding system that goes from a continuously spoken natural language sentence to its meaning and the consequent access to a database When we started in 1983 we had some expertise in small vocabulary syntax driven connected word speech recognition using Hidden Markov Models in written natural lan guage understanding and in hardware design mainly based upon bit slice microprocessors   Robust Automatic Speech Recognition Jinyu Li,Li Deng,Reinhold Haeb-Umbach,Yifan Gong,2015-10-30 Robust Automatic Speech Recognition A Bridge to Practical Applications establishes a solid foundation for automatic speech recognition that is robust against acoustic environmental distortion It provides a thorough overview of classical and modern noise and reverberation robust techniques that have been developed over the past thirty years with an emphasis on practical methods that have been proven to be successful and which are likely to be further developed for future applications The strengths and weaknesses of robustness enhancing speech recognition techniques are carefully analyzed The book covers noise robust techniques designed for acoustic models which are based on both Gaussian mixture models and deep neural networks In addition a guide to selecting the best methods for practical applications is provided The reader will Gain a unified deep and systematic understanding of the state of the art technologies for robust speech recognition Learn the links and relationship between alternative technologies for robust speech recognition Be able to use the technology analysis and categorization detailed in the book to guide future technology development Be able to develop new noise robust methods in the current era of deep learning for acoustic modeling in speech recognition The first book that provides a comprehensive review on noise and reverberation robust speech recognition methods in the era of deep neural networks Connects robust speech recognition techniques to machine learning paradigms with rigorous mathematical treatment Provides elegant and structural ways to categorize and analyze noise robust speech recognition techniques Written by leading researchers who have been actively working on the subject matter in both industrial and academic organizations for many years   *Springer Handbook of Speech Processing* Jacob Benesty,M. M. Sondhi,Yiteng Huang,2007-11-28 This handbook plays a fundamental role in sustainable progress in speech research and development With an accessible format and with accompanying DVD Rom it targets three categories of readers graduate students professors and active researchers in academia and engineers in industry who need to understand or implement some specific algorithms for their speech related products It is a superb source of application oriented

authoritative and comprehensive information about these technologies this work combines the established knowledge derived from research in such fast evolving disciplines as Signal Processing and Communications Acoustics Computer Science and Linguistics   Spoken Language Processing Xuedong Huang,Alejandro Acero,Hsiao-Wuen Hon,2001 Spoken Language Processing draws on the latest advances and techniques from multiple fields computer science electrical engineering acoustics linguistics mathematics psychology and beyond Starting with the fundamentals it presents all this and more Essential background on speech production and perception probability and information theory and pattern recognition Extracting information from the speech signal useful representations and practical compression solutions Modern speech recognition techniques hidden Markov models acoustic and language modeling improving resistance to environmental noises search algorithms and large vocabulary speech recognition Text to speech analyzing documents pitch and duration controls trainable synthesis and more Spoken language understanding dialog ma   **Speech Recognition Algorithms Using Weighted Finite-State Transducers** Takaaki Hori,Atsushi Nakamura,2022-05-31 This book introduces the theory algorithms and implementation techniques for efficient decoding in speech recognition mainly focusing on the Weighted Finite State Transducer WFST approach The decoding process for speech recognition is viewed as a search problem whose goal is to find a sequence of words that best matches an input speech signal Since this process becomes computationally more expensive as the system vocabulary size increases research has long been devoted to reducing the computational cost Recently the WFST approach has become an important state of the art speech recognition technology because it offers improved decoding speed with fewer recognition errors compared with conventional methods However it is not easy to understand all the algorithms used in this framework and they are still in a black box for many people In this book we review the WFST approach and aim to provide comprehensive interpretations of WFST operations and decoding algorithms to help anyone who wants to understand develop and study WFST based speech recognizers We also mention recent advances in this framework and its applications to spoken language processing Table of Contents Introduction Brief Overview of Speech Recognition Introduction to Weighted Finite State Transducers Speech Recognition by Weighted Finite State Transducers Dynamic Decoders with On the fly WFST Operations Summary and Perspective   Automatic Speech and Speaker Recognition Joseph Keshet,Samy Bengio,2009-04-27 This book discusses large margin and kernel methods for speech and speaker recognition Speech and Speaker Recognition Large Margin and Kernel Methods is a collation of research in the recent advances in large margin and kernel methods as applied to the field of speech and speaker recognition It presents theoretical and practical foundations of these methods from support vector machines to large margin methods for structured learning It also provides examples of large margin based acoustic modelling for continuous speech recognizers where the grounds for practical large margin sequence learning are set Large margin methods for discriminative language modelling and text independent speaker verification are also addressed in this book Key Features Provides an up to date snapshot of

the current state of research in this field Covers important aspects of extending the binary support vector machine to speech and speaker recognition applications Discusses large margin and kernel method algorithms for sequence prediction required for acoustic modeling Reviews past and present work on discriminative training of language models and describes different large margin algorithms for the application of part of speech tagging Surveys recent work on the use of kernel approaches to text independent speaker verification and introduces the main concepts and algorithms Surveys recent work on kernel approaches to learning a similarity matrix from data This book will be of interest to researchers practitioners engineers and scientists in speech processing and machine learning fields *Proceedings of the 2nd International Conference on Cognitive Based Information Processing and Applications (CIPA 2022)* Bernard J. Jansen,Qingyuan Zhou,Jun Ye,2023-04-10 This book contains papers presented at the 2nd International Conference on Cognitive based Information Processing and Applications CIPA in Changzhou China from September 22 to 23 2022 The book is divided into a 2 volume series and the papers represent the various technological advancements in network information processing graphics and image processing medical care machine learning smart cities It caters to postgraduate students researchers and practitioners specializing and working in the area of cognitive inspired computing and information processing **Comparison of Algorithms for Speech Recognition** Murugesh Krishnamurthy,1998 *Speech Recognition and Understanding* Pietro Laface,Renato DeMori,2012-12-06 The book collects the contributions to the NATO Advanced Study Institute on Speech Recognition and Understanding Recent Advances Trends and Applications held in Cetraro Italy during the first two weeks of July 1990 This Institute focused on three topics that are considered of particular interest and rich of i p novation by researchers in the fields of speech recognition and understanding Advances in Hidden Markov modeling connectionist approaches to speech and language modeling and linguistic processing including language and dialogue modeling The purpose of any ASI is that of encouraging scientific communications between researchers of NATO countries through advanced tutorials and presentations excellent tutorials were offered by invited speakers that present in this book 15 papers which sum marize or detail the topics covered in their lectures The lectures were complemented by discussions panel sections and by the presentation of related works carried on by some of the attending researchers these presentations have been collected in 42 short contributions to the Proceedings This volume that the reader can find useful for an overview although incomplete of the state of the art in speech understanding is divided into 6 Parts **New Systems and Architectures for Automatic Speech Recognition and Synthesis** Renato DeMori,Ching Y. Suen,2012-12-06 Proceedings of the NATO Advanced Study Institute on New Systems and Architecture for Automatic Speech Recognition and Synthesis held at Bonas Gers France 2 14 July 1984 *Neural Networks for Speech and Sequence Recognition* Yoshua Bengio,1996 Sequence recognition is a crucial element in many applications in the fields of speech analysis control and modeling This book applies the techniques of neural networks and hidden Markov models to the problems of sequence recognition and as such will prove valuable to researchers

and graduate students alike   **The Transactions of the Institute of Electronics and Communication Engineers of Japan** ,1982   *Scientific and Technical Aerospace Reports* ,1983 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database   **High-Performance VLSI Signal Processing Innovative Architectures and Algorithms, Systems Design and Applications** K. J. Ray Liu,Kung Yao,1998 Electrical Engineering Signal Processing High Performance VLSI Signal Processing Innovative Architectures and Algorithms Volume 2 Systems Design And Applications The second volume in a two volume set High Performance VLSI Signal Processing Innovative Architectures and Algorithms brings together the most innovative papers in the field focused introductory material and extensive references The editors present timely coverage of the latest design tools design environments and implementations of VLSI signal processing systems These volumes will serve as vital resources for engineers who want a comprehensive knowledge of the extremely interdisciplinary field of high performance VLSI processing The editors provide a practical understanding of the merits of total system design through an insightful synergistic presentation of methodology architecture and infrastructure Each volume features Major papers that span the wide range of research areas in the field Chapter introductions including historical perspectives Numerous applications oriented design examples Coverage of current and future technological trends

   Automatic Speech Recognition Kai-Fu Lee,1988-10-31 Speech Recognition has a long history of being one of the difficult problems in Artificial Intelligence and Computer Science As one goes from problem solving tasks such as puzzles and chess to perceptual tasks such as speech and vision the problem characteristics change dramatically knowledge poor to knowledge rich low data rates to high data rates slow response time minutes to hours to instantaneous response time These characteristics taken together increase the computational complexity of the problem by several orders of magnitude Further speech provides a challenging task domain which embodies many of the requirements of intelligent behavior operate in real time exploit vast amounts of knowledge tolerate errorful unexpected unknown input use symbols and abstractions communicate in natural language and learn from the environment Voice input to computers offers a number of advantages It provides a natural fast hands free eyes free location free input medium However there are many as yet unsolved problems that prevent routine use of speech as an input device by non experts These include cost real time response speaker independence robustness to variations such as noise microphone speech rate and loudness and the ability to handle non grammatical speech Satisfactory solutions to each of these problems can be expected within the next decade Recognition of unrestricted spontaneous continuous speech appears unsolvable at present However by the addition of simple constraints such as clarification dialog to resolve ambiguity we believe it will be possible to develop systems capable of accepting very large vocabulary continuous speechdictation   Publications - International Congress on Acoustics ,1989   *ACM Transactions on Programming Languages and Systems* Association for Computing Machinery,1994

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