Hidden Markov Models Baum Welch Algorithm

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Hidden Markov Models Baum Welch Algorithm ***2023-01-18***

SUTTON BLAZE

Artificial Intelligence and Computational Intelligence American Institute of Physics
Abstract: "This report describes a new technique for inducing the structure of Hidden Markov Models from data which is based on the general 'model merging' strategy (Omohundro 1992). The process begins with a maximum likelihood HMM that directly encodes the training data. Successively more general models are produced by merging HMM states. A Bayesian posterior probability criterion is used to determine which states to merge and when to stop generalizing. The procedure may be considered a heuristic search for the HMM structure with the highest posterior probability. We discuss a variety of possible priors for HMMs, as well as a number of approximations which improve the computational efficiency of the algorithm. We studied three applications to evaluate the procedure. The first compares the merging algorithm with the standard Baum-Welch approach in inducing simple finite-state languages from small, positive- only training samples. We found that the merging procedure is more robust and accurate, particularly with a small amount of training data. The second application uses labelled speech data from the TIMIT database to build compact, multiple-pronunciation word models that can be used in speech recognition. Finally, we describe how the algorithm was incorporated in an operational speech understanding system, where it is combined with neural network acoustic likelihood estimators to improve performance over single-pronunciation word models."
Theory and Implementation using MATLAB® Springer
We address the problem of learning discrete hidden Markov models from very long sequences of observations. Incremental versions of the Baum-Welch algorithm that approximate the beta-

values used in the backward procedure are commonly used for this problem since their memory complexity is independent of the sequence length. However, traditional approaches have two main disadvantages: the approximation of the beta-values deviates far from the real values, and the learning algorithm requires previous knowledge of the topology of the model. This dissertation describes a new incremental Baum-Welch algorithm with a novel backward procedure that improves the approximation of the â-values based on a one-step lookahead in the training sequence and investigates heuristics to prune unnecessary states from an initial complex model. Two new approaches for pruning, greedy and controlled, are introduced and a novel method for identification of ill-conditioned models is presented. Incremental learning of multiple independent observations is also investigated. We justify the new approaches analytically and report empirical results that show they converge faster than the traditional Baum-Welch algorithm using fewer computer resources. Furthermore, we demonstrate that the new learning algorithms converge faster than the previous incremental approaches and can be used to perform online learning of high-quality models useful for classification tasks. Finally, this dissertation explores the use of the new algorithms for anomaly detection in computer systems, that improve our previous research work on detectors based on hidden Markov models integrated into real-world monitoring systems of high-performance computers.

Inference in Hidden Markov Models CRC Press

Machine learning techniques provide cost-effective alternatives to traditional methods for extracting underlying relationships between information and data and for predicting future events by processing existing information to train models. Efficient Learning Machines explores the major topics of machine learning, including knowledge discovery, classifications, genetic algorithms, neural networking, kernel methods, and biologically-inspired techniques. Mariette Awad and Rahul Khanna's synthetic approach weaves together the theoretical exposition, design principles, and practical applications of efficient machine learning. Their experiential emphasis, expressed in their close analysis of sample algorithms throughout the book, aims to equip engineers, students of engineering, and system designers to design and create new and more efficient machine learning systems. Readers of Efficient Learning Machines will learn how to recognize and analyze the problems that machine learning technology can solve for them, how to implement and deploy standard solutions to sample problems, and how to design new systems and solutions. Advances in computing performance, storage, memory, unstructured information retrieval, and cloud computing have coevolved with a new generation of machine learning paradigms and big data analytics, which the authors present in the conceptual context of their traditional precursors. Awad and Khanna explore current developments in the deep learning techniques of deep neural networks, hierarchical temporal memory, and cortical algorithms. Nature suggests sophisticated learning techniques that deploy simple rules to generate highly intelligent and organized behaviors with adaptive, evolutionary, and distributed properties. The authors examine the most popular biologically-inspired algorithms, together with a sample application to distributed datacenter

management. They also discuss machine learning techniques for addressing problems of multi-objective optimization in which solutions in real-world systems are constrained and evaluated based on how well they perform with respect to multiple objectives in aggregate. Two chapters on support vector machines and their extensions focus on recent improvements to the classification and regression techniques at the core of machine learning.

Hidden Markov Models Cambridge University Press

Hidden Markov Models (HMMs) are ubiquitously used in applications such as speech recognition and gene prediction that involve inferring latent variables given observations. For the past few decades, the predominant technique used to infer these hidden variables has been the Baum-Welch algorithm. This thesis utilizes insights from two related fields. The first insight is from Angluin's seminal paper on learning regular sets from queries and counterexamples, which produces a simple and intuitive algorithm that efficiently learns deterministic finite automata. The second insight follows from a careful analysis of the representation of HMMs as matrices and realizing that matrices hold deeper meaning than simply entities used to represent the HMMs. This thesis takes Angluin's approach and nonnegative matrix factorization and applies them to learning HMMs. Angluin's approach fails and the reasons are discussed. The matrix factorization approach is successful, allowing us to produce a novel method of learning HMMs. The new method is combined with Baum-Welch into a hybrid algorithm. We evaluate the algorithm by comparing its performance in learning selected HMMs to the Baum-Welch algorithm. We empirically show that our algorithm is able to perform better than the Baum-Welch algorithm for HMMs with at most six states that have dense output and transition matrices. For these HMMs, our algorithm is shown to perform 22.65% better on average by the Kullback-Liebler measure.

IFIP WG 6.3/7.3 International Workshop, PERFORM 2010, in Honor of Günter Haring on the Occasion of His Emeritus Celebration, Vienna, Austria, October 14-16, 2010, Revised Selected Papers Springer

A comprehensive introduction to machine learning that uses probabilistic models and inference as a unifying approach. Today's Web-enabled deluge of electronic data calls for automated methods of data analysis. Machine learning provides these, developing methods that can automatically detect patterns in data and then use the uncovered patterns to predict future data. This textbook offers a comprehensive and self-contained introduction to the field of machine learning, based on a unified, probabilistic approach. The coverage combines breadth and depth, offering necessary background material on such topics as probability, optimization, and linear algebra as well as discussion of recent developments in the field, including conditional random fields, L1 regularization, and deep learning. The book is written in an informal, accessible style, complete with pseudo-code for the most important algorithms. All topics are copiously illustrated with color images and worked examples drawn from such application domains as biology, text processing, computer vision, and robotics. Rather than providing a cookbook of different heuristic methods, the book stresses a principled model-based approach, often using the language of graphical

models to specify models in a concise and intuitive way. Almost all the models described have been implemented in a MATLAB software package—PMTK (probabilistic modeling toolkit)—that is freely available online. The book is suitable for upper-level undergraduates with an introductory-level college math background and beginning graduate students.

Grokking Machine Learning Cambridge University Press

This book presents, in an integrated form, both the analysis and synthesis of three different types of hidden Markov models. Unlike other books on the subject, it is generic and does not focus on a specific theme, e.g. speech processing. Moreover, it presents the translation of hidden Markov models' concepts from the domain of formal mathematics into computer codes using MATLAB®. The unique feature of this book is that the theoretical concepts are first presented using an intuition-based approach followed by the description of the fundamental algorithms behind hidden Markov models using MATLAB®. This approach, by means of analysis followed by synthesis, is suitable for those who want to study the subject using a more empirical approach. Key Selling Points: Presents a broad range of concepts related to Hidden Markov Models (HMM), from simple problems to advanced theory Covers the analysis of both continuous and discrete Markov chains Discusses the translation of HMM concepts from the realm of formal mathematics into computer code Offers many examples to supplement mathematical notation when explaining new concepts

4th International Conference, AICI 2012, Chengdu, China, October 26-28, 2012, Proceedings BLACK WHITE

Please note that the content of this book primarily consists of articles available from Wikipedia or other free sources online. Pages: 102. Chapters: Bayesian networks, Markov models, Markov chain, Queueing theory, Snakes and ladders, Hidden Markov model, Poisson process, Reinforcement learning, Burst error, Mark V Shaney, Kalman filter, PageRank, Multiple sequence alignment, Models of DNA evolution, Forward-backward algorithm, Path dependence, Belief propagation, Structural equation modeling, Viterbi algorithm, Algorithmic composition, Part-of-speech tagging, Gene prediction, Google matrix, Markov switching multifractal, Conditional random field, Influence diagram, Markov random field, Markov chain Monte Carlo, Bayesian inference in phylogeny, Graphical models for protein structure, Queueing model, Pop music automation, Dynamic Markov compression, Subshift of finite type, Stochastic matrix, Language model, Examples of Markov chains, Hierarchical Bayes model, Factor graph, Markov property, Path analysis, Detailed balance, Bernoulli scheme, Variational message passing, Latent variable, Layered hidden Markov model, Markov partition, Hierarchical hidden Markov model, Discrete phase-type distribution, GLIMMER, Kolmogorov backward equations, Baum-Welch algorithm, Dependability state model, Plate notation, Junction tree algorithm, Variable-order Bayesian network, Iterative Viterbi decoding, Markovian discrimination, Forward algorithm, Entropy rate, Hidden semi-Markov model, Maximum entropy Markov model, Population process, Markov blanket, Collider, Soft output Viterbi algorithm, Moral graph, M-separation, Dynamics of Markovian particles, Markov chain geostatistics, Quantum Markov chain, Transiogram, Ancestral graph, Causal Markov condition, Poisson hidden Markov model, Dynamic

Bayesian network.
Speech & Language Processing Springer
Abstract: "We present a learning algorithm for hidden Markov models with continuous state and observation spaces. All necessary probability density functions are approximated using samples, along with density trees generated from such samples. A Monte Carlo version of Baum-Welch (EM) is employed to learn models from data, just as in regular HMM learning. Regularization during learning is obtained using an exponential shrinking technique. The shrinkage factor, which determines the effective capacity of the learning algorithm, is annealed down over multiple iterations of Baum-Welch, and early stopping is applied to select the right model. We prove that under mild assumptions, Monte Carlo Hidden Markov Models converge to a local maximum in likelihood space, just like conventional HMMs. In addition, we provide empirical results obtained in a gesture recognition domain, which illustrate the appropriateness of the approach in practice."
Bayesian Reasoning and Machine Learning Hidden Markov ModelsTheory and Applications
Drawing on the authors' extensive research in the analysis of categorical longitudinal data, Latent Markov Models for Longitudinal Data focuses on the formulation of latent Markov models and the practical use of these models. Numerous examples illustrate how latent Markov models are used in economics, education, sociology, and other fields. The R and MATLAB® routines used for the examples are available on the authors' website. The book provides you with the essential background on latent variable models, particularly the latent class model. It discusses how the Markov chain model and the latent class model represent a useful paradigm for latent Markov models. The authors illustrate the assumptions of the basic version of the latent Markov model and introduce maximum likelihood estimation through the Expectation-Maximization algorithm. They also cover constrained versions of the basic latent Markov model, describe the inclusion of the individual covariates, and address the random effects and multilevel extensions of the model. After covering advanced topics, the book concludes with a discussion on Bayesian inference as an alternative to maximum likelihood inference. As longitudinal data become increasingly relevant in many fields, researchers must rely on specific statistical and econometric models tailored to their application. A complete overview of latent Markov models, this book demonstrates how to use the models in three types of analysis: transition analysis with measurement errors, analyses that consider unobserved heterogeneity, and finding clusters of units and studying the transition between the clusters.
Bayesian Networks, Markov Models, Markov Chain, Queueing Theory, Snakes and Ladders, Hidden Markov Model, Poisson Process, Reinforce University-Press.org
Hidden Markov models (HMMs) originally emerged in the domain of speech recognition. In recent years, they have attracted growing interest in the area of computer vision as well. This book is a collection of articles on new developments in the theory of HMMs and their application in computer vision. It addresses topics such as handwriting recognition, shape recognition, face and gesture recognition, tracking, and image database retrieval. This book is also published as a special issue of the International

Journal of Pattern Recognition and Artificial Intelligence (February 2001). Contents: Introduction: A Simple Complex in Artificial Intelligence and Machine Learning (B H Juang)An Introduction to Hidden Markov Models and Bayesian Networks (Z Chahramani)Multi-Lingual Machine Printed OCR (P Natarajan et al.)Using a Statistical Language Model to Improve the Performance of an HMM-Based Cursive Handwriting Recognition System (U-V Marti & H Bunke)A 2-D HMM Method for Offline Handwritten Character Recognition (H-S Park et al.)Data-Driven Design of HMM Topology for Online Handwriting Recognition (J J Lee et al.)Hidden Markov Models for Modeling and Recognizing Gesture Under Variation (A D Wilson & A F Bobick)Sentence Lipreading Using Hidden Markov Model with Integrated Grammar (K Yu et al.)Tracking and Surveillance in Wide-Area Spatial Environments Using the Abstract Hidden Markov Model (H H Bui et al.)Shape Tracking and Production Using Hidden Markov Models (T Caelli et al.)An Integrated Approach to Shape and Color-Based Image Retrieval of Rotated Objects Using Hidden Markov Models (S Müller et al.) Readership: Graduate students of computer science, electrical engineering and related fields, as well as researchers at academic and industrial institutions. Keywords:Hidden Markov Models;Gesture Recognitoin;Bayesian Networks;Optical Character Recognition;Handwriting Character Recognition;Cartography;Shape Extraction;Image Feature Extraction.

Hidden Markov Models and Dynamical Systems CRC Press

A novel two-channel algorithm is proposed in this paper for discriminative training of Hidden Markov Models (HMMs). It adjusts the symbol emission coefficients of an existing HMM to maximize the separable distance between a pair of confusable training samples. The method is applied to identify the visemes of visual speech. The results indicate that the two-channel training method provides better accuracy on separating similar visemes than the conventional Baum-Welch estimation.

Theory and Implementation using MATLAB® Springer Science & Business Media

This volume proceedings contains revised selected papers from the 4th International Conference on Artificial Intelligence and Computational Intelligence, AICI 2012, held in Chengdu, China, in October 2012. The total of 163 high-quality papers presented were carefully reviewed and selected from 724 submissions. The papers are organized into topical sections on applications of artificial intelligence, applications of computational intelligence, data mining and knowledge discovery, evolution strategy, expert and decision support systems, fuzzy computation, information security, intelligent control, intelligent image processing, intelligent information fusion, intelligent signal processing, machine learning, neural computation, neural networks, particle swarm optimization, and pattern recognition.

Statistical Methods for Speech Recognition CRC Press

The Application of Hidden Markov Models in Speech Recognition presents the core architecture of a HMM-based LVCSR system and proceeds to describe the various refinements which are needed to achieve state-of-the-art performance.

Incremental Learning of Discrete Hidden Markov Models Now Publishers Inc

The purpose of this book is to give a thorough and systematic introduction to probabilistic modeling in bioinformatics. The book

contains a mathematically strict and extensive presentation of the kind of probabilistic models that have turned out to be useful in genome analysis. Questions of parametric inference, selection between model families, and various architectures are treated. Several examples are given of known architectures (e.g., profile HMM) used in genome analysis. Audience: This book will be of interest to advanced undergraduate and graduate students with a fairly limited background in probability theory, but otherwise well trained in mathematics and already familiar with at least some of the techniques of algorithmic sequence analysis.

Latent Markov Models for Longitudinal Data Springer

Hidden Markov Models (HMMs) is a powerful probabilistic tool with many potential uses, but its application in quality control has not yet been completely explored. In this study, we develop an HMMs-base methodology to identify (concurrent) patterns in Shewhart control charts. The proposed model integrates Hidden Markov Models and hierarchical clustering method to effectively group observations based on their statistical similarities, which allows, identifying the number of distributions observations are generated from. To improve the performance and robustness of the proposed approach, we modify the Baum-Welch algorithm based on the concepts of Bayesian Information Criterion (BIC). The proposed mechanism will provide an effective and efficient tool to identify different type of patterns in the process. Simulations studies are conducted to evaluate the performance of the proposed method under various scenarios. In addition, the model has been applied in a healthcare setting to identify various trajectories of chronic diseases over time.

Hidden Markov Models University-Press.org

Hidden Markov Models for Time Series: An Introduction Using R, Second Edition illustrates the great flexibility of hidden Markov models (HMMs) as general-purpose models for time series data. The book provides a broad understanding of the models and their uses. After presenting the basic model formulation, the book covers estimation, forecasting, decoding, prediction, model selection, and Bayesian inference for HMMs. Through examples and applications, the authors describe how to extend and generalize the basic model so that it can be applied in a rich variety of situations. The book demonstrates how HMMs can be applied to a wide range of types of time series: continuous-valued, circular, multivariate, binary, bounded and unbounded counts, and categorical observations. It also discusses how to employ the freely available computing environment R to carry out the computations. Features Presents an accessible overview of HMMs Explores a variety of applications in ecology, finance, epidemiology, climatology, and sociology Includes numerous theoretical and programming exercises Provides most of the analysed data sets online New to the second edition A total of five chapters on extensions, including HMMs for longitudinal data, hidden semi-Markov models and models with continuous-valued state process New case studies on animal movement, rainfall occurrence and capture-recapture data

A Two-channel Training Algorithm for Hidden Markov Model to Identify Visual Speech Elements CRC Press

A comprehensive overview of data science covering the analytics, programming, and business skills necessary to master the discipline Finding a good data scientist has been likened to hunting for a unicorn: the required combination of technical skills

is simply very hard to find in one person. In addition, good data science is not just rote application of trainable skill sets; it requires the ability to think flexibly about all these areas and understand the connections between them. This book provides a crash course in data science, combining all the necessary skills into a unified discipline. Unlike many analytics books, computer science and software engineering are given extensive coverage since they play such a central role in the daily work of a data scientist. The author also describes classic machine learning algorithms, from their mathematical foundations to real-world applications. Visualization tools are reviewed, and their central importance in data science is highlighted. Classical statistics is addressed to help readers think critically about the interpretation of data and its common pitfalls. The clear communication of technical results, which is perhaps the most undertrained of data science skills, is given its own chapter, and all topics are explained in the context of solving real-world data problems. The book also features: • Extensive sample code and tutorials using Python™ along with its technical libraries • Core technologies of "Big Data," including their strengths and limitations and how they can be used to solve real-world problems • Coverage of the practical realities of the tools, keeping theory to a minimum; however, when theory is presented, it is done in an intuitive way to encourage critical thinking and creativity • A wide variety of case studies from industry • Practical advice on the realities of being a data scientist today, including the overall workflow, where time is spent, the types of datasets worked on, and the skill sets needed The Data Science Handbook is an ideal resource for data analysis methodology and big data software tools. The book is appropriate for people who want to practice data science, but lack the required skill sets. This includes software professionals who need to better understand analytics and statisticians who need to understand software. Modern data science is a unified discipline, and it is presented as such. This book is also an appropriate reference for researchers and entry-level graduate students who need to learn real-world analytics and expand their skill set. FIELD CADY is the data scientist at the Allen Institute for Artificial Intelligence, where he develops tools that use machine learning to mine scientific literature. He has also worked at Google and several Big Data startups. He has a BS in physics and math from Stanford University, and an MS in computer science from Carnegie Mellon.

Proceedings of the 2nd International Conference on Intelligent Human Systems Integration (IHSI 2019): Integrating People and Intelligent Systems, February 7-10, 2019, San Diego, California, USA World Scientific

Hidden Markov ModelsTheory and ApplicationsBoD – Books on Demand

Machine Learning John Wiley & Sons

The overall goal of this project (Phases I & II) was to develop computerized procedures that detect Road Weather Information System (RWIS) sensor malfunctions. In the first phase of the research we applied three classification algorithms and six regression algorithms to data generated by RWIS sensors in order to predict malfunctions. In this phase we investigate the use of Hidden Markov models as predictors of sensor values. The Hidden Markov model (HMM) is a technique used to model a sequence of temporal events. For example, suppose we have the sequence of

values produced by a given sensor over a fixed time period. An HMM can be used to produce this sequence and then to determine the probability of occurrence of another sequence of values, such as that produced by the given sensor for a subsequent time period. If the actual values produced by the sensor deviate from the predicted sequence then a malfunction may have occurred. This report provides an overview of the Hidden Markov model and three algorithms, namely, the Forward-Backward algorithms, the Baum-Welch algorithm, and the Viterbi algorithm, that were used in our development of Hidden Markov models to predict sensor values. We performed a series of experiments to evaluate the use of HMMs as predictors of temperature and precipitation sensor values.

A Baum-Welch Algorithm for Noisy Vector Fields for Classification and Synthesis of Textures Using Non-Symmetric Half-Plane

Springer Nature

We address the problem of learning discrete hidden Markov models from very long sequences of observations. Incremental versions of the Baum-Welch algorithm that approximate the beta-values used in the backward procedure are commonly used for this problem since their memory complexity is independent of the sequence length. However, traditional approaches have two main disadvantages: the approximation of the beta-values deviates far from the real values, and the learning algorithm requires previous knowledge of the topology of the model. This dissertation describes a new incremental Baum-Welch algorithm with a novel backward procedure that improves the approximation of the â-values based on a one-step lookahead in the training sequence and investigates heuristics to prune unnecessary states from an initial complex model. Two new approaches for pruning, greedy and controlled, are introduced and a novel method for identification of ill-conditioned models is presented. Incremental learning of multiple independent observations is also investigated. We justify the new approaches analytically and report empirical results that show they converge faster than the traditional Baum-Welch algorithm using fewer computer resources. Furthermore, we demonstrate that the new learning algorithms converge faster than the previous incremental approaches and can be used to perform online learning of high-quality models useful for classification tasks. Finally, this dissertation explores the use of the new algorithms for anomaly detection in computer systems, that improve our previous research work on detectors based on hidden Markov models integrated into real-world monitoring systems of high-performance computers.