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# Natural Language Generation using Dependency Tree Decoding for Spoken Dialog Systems

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**ABSTRACT** In this paper, we propose a new natural language generation method for spoken dialog systems and demonstrate its capacity. Studies on natural language generation often employ sequence decoding, which generates the words comprising a sentence in sequential order and uses the input generated by each word in the previous step. In contrast, we propose a decoding method that employs a sequence generated by traversing a dependency tree with feed input to a pair consisting of a parent and sibling in the dependency tree. As a result, the most important words are generated first, thereby enabling words with greater relevance to be fed into the process. At prediction time, our model generates dependency trees and converts the trees into sentences. The proposed decoding method was evaluated by re-implementing a semantically controlled Long Short-Term Memory (SC-LSTM) structure for natural language generation, and the input and predicted sequence were converted to allow dependency tree decoding. The experimental results indicated that our suggested approach, i.e., dependency tree decoding, dramatically elevates the BLEU-score and naturalness. Furthermore, when creating sentences with n-best using dependency tree decoding, the word-diversity of the output sentences was increased by approximately 6%, offering a more diverse sentence pattern.

**INDEX TERMS** Machine learning, Multi-layer neural network, human computer interaction, natural language processing, dependency parsing, spoken dialog system

## I. INTRODUCTION

The spoken dialog system (SDS) is a computer system that was designed to converse with users using speech and natural language, and plays a crucial role in human-machine interaction. As shown in Fig. 1, SDS is generally composed of automatic speech recognition (ASR), natural language understanding (NLU), dialog management (DM), natural language generation (NLG), and text-to-speech synthesis (TTS) [1][2]. NLG in SDS components generates natural language sentences that correspond to structured semantic representations. The semantic expression includes the intention and the information an SDS intends to convey. Thus, effective NLG dramatically improves the usability of human-machine interaction.

In recent years, various deep neural network (DNN) technologies have been applied to natural language processing tasks. Specifically, the recurrent neural network

(RNN) has demonstrated unequivocal advantages in tasks such as machine translation [3][4], image captioning [5][6], video captioning [7][8][9], video action recognition [10][11], video retrieval [12], information extraction [13][14], and NLG [15][16]. Among these applications, NLG is a particularly challenging task in an SDS. In this scenario, RNN-based approaches have not yet replaced the template-based approach because they do not provide stable performance. Template-based NLG provides reliable performance and is conceptually intuitive [17]. However, template-based NLG requires the construction of templates for each type of dialog act the dialog manager could potentially return as output. Furthermore, responses obtained from template-based NLG are constrained to the same type of dialog act as the input, which can be tedious for an SDS user. We suggest that the adaptation of DNN-based NLG to

# Spoken Natural Language Dialog Systems

**Niels O. Bernsen, Hans Dybkjaer, Laila  
Dybkjaer**



## **Spoken Natural Language Dialog Systems:**

**Spoken Natural Language Dialog Systems** Ronnie W. Smith, D. Richard Hipp, 1995-02-02 As spoken natural language dialog systems technology continues to make great strides numerous issues regarding dialog processing still need to be resolved This book presents an exciting new dialog processing architecture that allows for a number of behaviors required for effective human machine interactions including problem solving to help the user carry out a task coherent subdialog movement during the problem solving process user model usage expectation usage for contextual interpretation and error correction and variable initiative behavior for interacting with users of differing expertise The book also details how different dialog problems in processing can be handled simultaneously and provides instructions and in depth result from pertinent experiments Researchers and professionals in natural language systems will find this important new book an invaluable addition to their libraries *Natural Language Dialog Systems and Intelligent Assistants* G.G. Lee, H.K. Kim, M. Jeong, J.-H. Kim, 2015-09-28 This book covers state of the art topics on the practical implementation of Spoken Dialog Systems and intelligent assistants in everyday applications It presents scientific achievements in language processing that result in the development of successful applications and addresses general issues regarding the advances in Spoken Dialog Systems with applications in robotics knowledge access and communication Emphasis is placed on the following topics speaker language recognition user modeling simulation evaluation of dialog system multi modality emotion recognition from speech speech data mining language resource and databases machine learning for spoken dialog systems and educational and healthcare applications Spoken Dialogue Systems Kristina Jokinen, Michael McTear, 2022-05-31 Considerable progress has been made in recent years in the development of dialogue systems that support robust and efficient human machine interaction using spoken language Spoken dialogue technology allows various interactive applications to be built and used for practical purposes and research focuses on issues that aim to increase the system s communicative competence by including aspects of error correction cooperation multimodality and adaptation in context This book gives a comprehensive view of state of the art techniques that are used to build spoken dialogue systems It provides an overview of the basic issues such as system architectures various dialogue management methods system evaluation and also surveys advanced topics concerning extensions of the basic model to more conversational setups The goal of the book is to provide an introduction to the methods problems and solutions that are used in dialogue system development and evaluation It presents dialogue modelling and system development issues relevant in both academic and industrial environments and also discusses requirements and challenges for advanced interaction management and future research Table of Contents Preface Introduction to Spoken Dialogue Systems Dialogue Management Error Handling Case Studies Advanced Approaches to Dialogue Management Advanced Issues Methodologies and Practices of Evaluation Future Directions References Author Biographies **The Oxford Handbook of Computational Linguistics** Ruslan Mitkov, 2004 This handbook of computational linguistics written

for academics graduate students and researchers provides a state of the art reference to one of the most active and productive fields in linguistics

**EG-ICE 2021 Workshop on Intelligent Computing in Engineering** Abualdenien, Jimmy, Borrmann, André, Ungureanu, Lucian-Constantin, Hartmann, Timo, 2021-08-06 The 28th EG ICE International Workshop 2021 brings together international experts working at the interface between advanced computing and modern engineering challenges Many engineering tasks require open world resolutions to support multi actor collaboration coping with approximate models providing effective engineer computer interaction search in multi dimensional solution spaces accommodating uncertainty including specialist domain knowledge performing sensor data interpretation and dealing with incomplete knowledge While results from computer science provide much initial support for resolution adaptation is unavoidable and most importantly feedback from addressing engineering challenges drives fundamental computer science research Competence and knowledge transfer goes both ways Der 28 Internationale EG ICE Workshop 2021 bringt internationale Experten zusammen die an der Schnittstelle zwischen fortgeschrittener Datenverarbeitung und modernen technischen Herausforderungen arbeiten Viele ingenieurwissenschaftliche Aufgaben erfordern Open World Resolutionen um die Zusammenarbeit mehrerer Akteure zu unterstützen mit approximativen Modellen umzugehen eine effektive Interaktion zwischen Ingenieur und Computer zu ermöglichen in mehrdimensionalen Lösungsräumen zu suchen Unsicherheiten zu berücksichtigen einschließlich fachspezifischen Domänenwissens Sensordateninterpretation durchzuführen und mit unvollständigem Wissen umzugehen Während die Ergebnisse aus der Informatik analog viel Unterstützung für die Lösung bieten ist eine Anpassung unvermeidlich und am wichtigsten ist dass das Feedback aus der Bewältigung technischer Herausforderungen die computer wissenschaftliche Grundlagenforschung vorantreibt Kompetenz und Wissenstransfer gehen in beide Richtungen

**Designing Interactive Speech Systems** Niels O. Bernsen, Hans Dybkjaer, Laila Dybkjaer, 2012-12-06 Designing Interactive Speech Systems describes the design and implementation of spoken language dialogue within the context of SLDS spoken language dialogue systems development Using an applications oriented SLDS developed through the Danish Dialogue project the authors describe the complete process involved in designing such a system and in doing so present several innovative practical tools such as dialogue design guidelines in depth evaluation methodologies and speech functionality analysis The approach taken is firmly applications oriented describing the results of research applicable to industry and showing how the development of advanced applications drives research rather than the other way around All those working on the research and development of spoken language services especially in the area of telecommunications will benefit from reading this book

*Perception in Multimodal Dialogue Systems* Elisabeth Andre, Laila Dybkjær, Heiko Neumann, Roberto Pieraccini, Michael Weber, 2008-06-11 This book constitutes the refereed proceedings of the 4th IEEE Tutorial and Research Workshop on Perception and Interactive Technologies for Speech Based Systems PIT 2008 held in Kloster Irsee Germany in June 2008 The 37 revised full papers presented together with 1 invited keynote lecture

were carefully selected from numerous submissions for inclusion in the book The papers are organized in topical sections on multimodal and spoken dialogue systems classification of dialogue acts and sound recognition of eye gaze head poses mimics and speech as well as combinations of modalities vocal emotion recognition human like and social dialogue systems and evaluation methods for multimodal dialogue systems

**Constructive Dialogue Modelling** Kristiina Jokinen, 2009-05-27

Dialogue management technology has developed rapidly over the years resulting in real time applications like telephony directories timetable enquiries and in car applications However the current technology is still largely based on models that use rigid command language type interactions and the users need to adapt their human communication strategies to the needs of the technology As an increasing number of interactive ubiquitous applications will appear challenges for interaction technology concern especially natural more human friendly communication Recent research has focused on developing speech based interactive systems that aim to increase the system s communicative competence By including aspects of interaction beyond simple speech recognition and question answer based interaction applications with more conversational interfaces have become possible New dialogue management technology needs to address the challenges in human technology interaction so that smart environments should not only enable user controlled command interfaces but equip applications with a capability that affords easy and friendly interactions with the user

**Dialogue Modelling Speech Interaction and Rational Agents** provides an overview of the current dialogue technology and research trends in spoken dialogue systems presenting a coherent perspective of AI based cooperative interaction management The book complements existing research regarding human computer interfaces speech and language technology and communication studies in general bringing different view points together and integrating them into a single point of reference

**Constructive Dialogue Modelling** Presents a guide to spoken dialogue technology and current research trends Provides an overview of human factors in dialogue systems and delivers a new metaphor for human computer interaction and computer as agent Explains the architecture of dialogue systems using examples from systems such as Interact and DUMAS Offers a comprehensive overview of original research into the new trends in speech dialogue technology in light of innovations such as ubiquitous computing This book will provide essential reading for industrial designers and interface engineers university researchers and teachers computer scientists human communication researchers speech and language technologists cognitive engineers cognitive scientists as well as social and media researchers and psychologists

Advanced students and researchers in computer science speech and language technologies psychology and communication research will find this text of interest

**Computational Models of Mixed-Initiative Interaction** Susan Haller, Susan McRoy, Alfred Kobsa, 1999-08-31

Computational Models of Mixed Initiative Interaction brings together research that spans several disciplines related to artificial intelligence including natural language processing information retrieval machine learning planning and computer aided instruction to account for the role that mixed initiative plays in the design of intelligent systems The ten contributions address the single issue of how control of an

interaction should be managed when abilities needed to solve a problem are distributed among collaborating agents Managing control of an interaction among humans and computers to gather and assemble knowledge and expertise is a major challenge that must be met to develop machines that effectively collaborate with humans This is the first collection to specifically address this issue *Ontology-Based Answer Selection in Dialog Systems* Christian Pretzsch,2006-11-13 Thesis M A from the year 2006 in the subject Computer Science Miscellaneous grade 1 1 University of Heidelberg Seminar f r Computerlinguistik Institut f r allgemeine und angewandte Sprachwissenschaft language English abstract In these days our daily life is more and more affected by computers chips electronic equipment et cetera Owing to this increase of technology even in common everyday objects like for example a fridge it is necessary to find a simple and intuitive way to interact with complex technology Natural language dialog systems could be the solution or at least a part of it how humans and machines could communicate or interact with each other With the help of dialog systems people could access information and technical functionality of computers in a natural way using linguistic in and output One of the main tasks of such dialog systems is to provide fast and appropriate answers to user s questions or requests The challenge therein is how do we find these answers out of the flood of information *Speech Technology* Fang Chen,Kristiina Jokinen,2010-07-01 This book gives an overview of the research and application of speech technologies in different areas One of the special characteristics of the book is that the authors take a broad view of the multiple research areas and take the multidisciplinary approach to the topics One of the goals in this book is to emphasize the application User experience human factors and usability issues are the focus in this book **Practical Spoken Dialog Systems** Deborah Dahl,2007-09-28 For professional speech researchers there is a rich technical literature covering many years of primary research in speech However this literature is not necessarily applicable to the needs of business people application developers and students who are interested in learning about the practical uses of speech technology On the other hand while existing introductory resources cover the basic mechanics of development of application development as well as aspects of the voice user interface they don t go far enough in dealing with the details that have to be taken into account to make spoken dialog systems successful in practice What s missing is information in between the in depth technical literature and the more introductory development resources The goal of this book is to provide information for anyone who wants to take the next step beyond the basics of current speech applications but isn t yet ready to dive into the technical literature It is hoped that this book will help project managers application developers and students gain a fuller and more complete understanding of spoken dialog technology and the practical aspects of developing and deploying spoken dialog applications **Fifth Conference on Applied Natural Language Processing** Association for Computational Linguistics,1997 *General Pipeline Architecture for Domain-Specific Dialogue Extraction from different IRC Channels* Ahmed Abouzeid,2017-06-21 Master s Thesis from the year 2017 in the subject Computer Science Applied grade 4 6 5 E tv s Lor nd University course Master s Degree in Computer Science language English abstract This thesis

proposes a general pipeline architecture for one on one dialogues extraction from many different IRC channels to extend the state of art work for the Ubuntu IRC channel Further more this thesis takes the advantage of the results from the pipeline and evaluates ESA on different extracted dialogues The power of an intelligent program to perform its task well depends primarily on the quantity and quality of knowledge it has about that task Advanced techniques and applications in Artificial Intelligence are highly depending on data which at the same time getting highly increased and are available over the web However for a computer to be able to manipulate information the latter should be in a form that makes it easy for a computer to manipulate That is many available unstructured data need to be collected and post processed in order to create structured information from the unstructured ones Recent advances in Data Driven Dialogue Systems made use of the Ubuntu published IRC channel conversations to extract one on one dialogues to use in Deep Learning methods A best response task performed by a Dialogue System can make use of a trained model on such dialogues In addition techniques in Natural Language Processing like Semantic Analysis had a remarkable progress Wikipedia Based Explicit Semantic Analysis ESA is an example where the problem of interpretation was improved for both Polysemy and Synonymy [1999 IEEE International Conference on Acoustics, Speech, and Signal Processing](#) ,1999 [Human Factors and Voice Interactive Systems](#) Daryle Gardner-Bonneau,1999 Human Factors and Voice Interactive Systems highlights the importance of human factors in speech technologies and presents and demonstrates the use of human factors principles methods techniques and tools in the design of speech enabled applications Included is coverage of automatic speech recognition synthetic speech and interactive voice response systems Some chapters are devoted to specific applications of speech technology and other chapters are either issue oriented or provide a comprehensive view of human factors knowledge and lessons learned in a specific applications area This book places special emphasis on interactive voice response IVR devoting seven of its fourteen chapters to both speech enabled and traditional touch tone based IVR applications Other chapters emphasize speech recognition application development natural language processing synthetic speech and the use of speech technology in assistive devices for people with disabilities to further the goal of universal access to information technology for all **Computational Linguistics** ,1997 **Spoken, Multilingual and Multimodal Dialogue Systems** Ramon Lopez Cozar Delgado,Masahiro Araki,2005-11-11 Dialogue systems are a very appealing technology with an extraordinary future Spoken Multilingual and Multimodal Dialogues Systems Development and Assessment addresses the great demand for information about the development of advanced dialogue systems combining speech with other modalities under a multilingual framework It aims to give a systematic overview of dialogue systems and recent advances in the practical application of spoken dialogue systems Spoken Dialogue Systems are computer based systems developed to provide information and carry out simple tasks using speech as the interaction mode Examples include travel information and reservation weather forecast information directory information and product order Multimodal Dialogue Systems aim to overcome the limitations of spoken dialogue

systems which use speech as the only communication means while Multilingual Systems allow interaction with users that speak different languages Presents a clear snapshot of the structure of a standard dialogue system by addressing its key components in the context of multilingual and multimodal interaction and the assessment of spoken multilingual and multimodal systems In addition to the fundamentals of the technologies employed the development and evaluation of these systems are described Highlights recent advances in the practical application of spoken dialogue systems This comprehensive overview is a must for graduate students and academics in the fields of speech recognition speech synthesis speech processing language and human computer interaction technology It will also prove to be a valuable resource to system developers working in these areas

**Ninth Conference of the European Chapter of the Association for Computational Linguistics** Association for Computational Linguistics. European Chapter. Conference,1999 [IUI ...](#)  
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