A Survey on Learning-Based Approaches for Modeling and Classification of Human–Machine Dialog Systems

Fuwei Cui, Qian Cui, and Yongduan Song, *Fellow, IEEE*

Abstract—With the rapid development from traditional machine learning (ML) to deep learning (DL) and reinforcement learning (RL), dialog system equipped with learning mechanism has become the most effective solution to address human–machine interaction problems. The purpose of this article is to provide a comprehensive survey on learning-based human–machine dialog systems with a focus on the various dialog models. More specifically, we first introduce the fundamental process of establishing a dialog model. Second, we examine the features and classifications of the system dialog model, expound some representative models, and also compare the advantages and disadvantages of different dialog models. Third, we comb the commonly used database and evaluation metrics of the dialog model. Furthermore, the evaluation metrics of these dialog models are analyzed in detail. Finally, we briefly analyze the existing issues and point out the potential future direction on the human–machine dialog systems.

Index Terms—Artificial intelligence (AI), deep learning (DL), dialog model, machine learning (ML), reinforcement learning (RL), sequence to sequence (Seq2Seq) model.

I. INTRODUCTION

ONE of the original research purposes of the human–machine dialog system is to pass the Turing test. And human beings have been studying dialog systems for half a century. Early dialog systems were based on artificial rules, such as Eliza (1966) [1], Parry (1975) [2] which passed the Turing test, and Alice (2009) [3] which won the Loebprize three times recently. Although the rule-based dialog system has achieved good results, the establishment of rules is laborious, and its transferability is poor. Most importantly, many rules eventually lead to the software system either too costly or seldom practical.
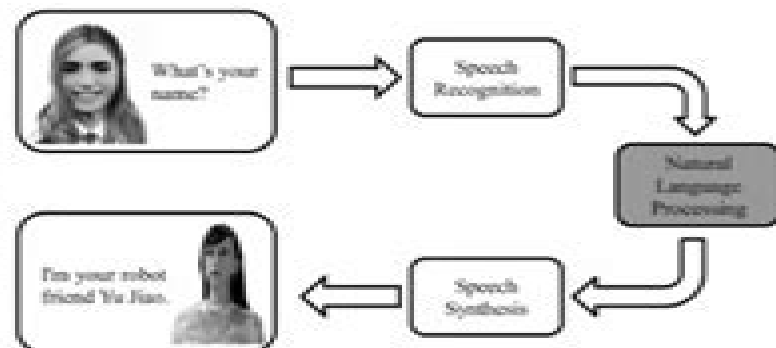
Fig. 1.   Composition of dialog system.

With the development of speech recognition [4]–[6], speech synthesis [7], [8], natural language processing [9], [10], and information retrieval (IR) [11], [12], especially deep learning (DL) [13]–[15] and reinforcement learning (RL) [54], some data-driven-based models that use DL or RL have been proposed, such as IR models, generation models, RL models, and hybrid models. And so far, many human–machine dialog products have emerged, such as Cortana and Microsoft Xiaobing in 2014, Baidu Duer and Ali Xiaomi in 2015, Apple Siri and Google Assistant in 2016, Tencent tinkling in 2017 and so on. Although the existing dialog system can communicate with human beings in some occasions, the system itself is not intelligent enough, calling for the implementation of much strong artificial intelligence (AI). Therefore, it is crucial to carry out extensive research on the dialog system, which makes it necessary to have a general grasp of the current research situation of the dialog system.

The dialog system is generally composed of speech recognition, natural language processing, speech synthesis (early template-based dialog model without speech recognition and speech synthesis module), as conceptually shown in Fig. 1, where the function of the speech recognition module is to convert human speech signal into text signal for the natural language understanding module. Next, the natural language

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Speech and Human-Machine Dialog Wolfgang Minker,Samir Bennacef,2013-03-23 Speech and Human Machine Dialog focuses on the dialog management component of a spoken language dialog system Spoken language dialog systems provide a natural interface between humans and computers These systems are of special interest for interactive applications and they integrate several technologies including speech recognition natural language understanding dialog management and speech synthesis Due to the conjunction of several factors throughout the past few years humans are significantly changing their behavior vis vis machines In particular the use of speech technologies will become normal in the professional domain and in everyday life The performance of speech recognition components has also significantly improved This book includes various examples that illustrate the different functionalities of the dialog model in a representative application for train travel information retrieval train time tables prices and ticket reservation Speech and Human Machine Dialog is designed for a professional audience composed of researchers and practitioners in industry This book is also suitable as a secondary text for graduate level students in computer science and engineering *Speech and Human-Machine Dialog* Wolfgang Minker,Samir Bennacef,2006-04-18 Speech and Human Machine Dialog focuses on the dialog management component of a spoken language dialog system Spoken language dialog systems provide a natural interface between humans and computers These systems are of special interest for interactive applications and they integrate several technologies including speech recognition natural language understanding dialog management and speech synthesis Due to the conjunction of several factors throughout the past few years humans are significantly changing their behavior vis vis machines In particular the use of speech technologies will become normal in the professional domain and in everyday life The performance of speech recognition components has also significantly improved This book includes various examples that illustrate the different functionalities of the dialog model in a representative application for train travel information retrieval train time tables prices and ticket reservation Speech and Human Machine Dialog is designed for a professional audience composed of researchers and practitioners in industry This book is also suitable as a secondary text for graduate level students in computer science and engineering **Situated Dialog in Speech-Based Human-Computer Interaction** Alexander Rudnicky,Antoine Raux,Ian Lane,Teruhisa Misu,2016-04-20 This book provides a survey of the state of the art in the practical implementation of Spoken Dialog Systems for applications in everyday settings It includes contributions on key topics in situated dialog interaction from a number of leading researchers and offers a broad spectrum of perspectives on research and development in the area In particular it presents applications in robotics knowledge access and communication and covers the following topics dialog for interacting with robots language understanding and generation dialog architectures and modeling core technologies and the analysis of human discourse and interaction The contributions are adapted and expanded contributions from the 2014 International Workshop on Spoken Dialog Systems IWSDS 2014 where researchers and developers from

industry and academia alike met to discuss and compare their implementation experiences analyses and empirical findings

Quality of Telephone-Based Spoken Dialogue Systems Sebastian Möller,2005-12-28 Quality of Telephone Based Spoken Dialogue Systems is a systematic overview of assessment evaluation and prediction methods for the quality of services such as travel and touristic information phone directory and messaging or telephone banking services A new taxonomy of quality of service is presented which serves as a tool for classifying assessment and evaluation methods for planning and interpreting evaluation experiments and for estimating quality A broad overview of parameters and evaluation methods is given both on a system component level and for a fully integrated system Three experimental investigations illustrate the relationships between system characteristics and perceived quality The resulting information is needed in all phases of system specification design implementation and operation Although Quality of Telephone Based Spoken Dialogue Systems is written from the perspective of an engineer in telecommunications it is an invaluable source of information for professionals in signal processing communication acoustics computational linguistics speech and language sciences human factor design and ergonomics **Interactive Collaborative Robotics** Andrey Ronzhin,Gerhard Rigoll,Roman Meshcheryakov,2016-08-15 This book constitutes the proceedings of the First International Conference on Interactive Collaborative Robotics ICR 2016 held in Budapest Hungary in August 2016 The 29 papers presented in this volume were carefully reviewed and selected from 48 submissions Text, Speech and Dialogue Petr Sojka,Aleš Horak,Ivan Kopecek,Karel Pala,2010-08-30 This book constitutes the refereed proceedings of the 13th International Conference on Text Speech and Dialogue TSD 2010 held in Brno Czech Republic September 2010 The 71 revised full papers presented together with 3 invited papers were carefully reviewed and selected from 144 submissions The topics of the conference include but are not limited to text corpora and tagging transcription problems in spoken corpora sense disambiguation links between text and speech oriented systems parsing issues multi lingual issues information retrieval and information extraction text topic summarization machine translation semantic web speech modeling speech recognition search in speech for IR and IE text to speech synthesis emotions and personality modeling user modeling knowledge representation in relation to dialogue systems assistive technologies based on speech and dialogue applied systems and software facial animation as well as visual speech synthesis **Dialogue Processing in Spoken Language Systems** Elisabeth Meier,Marion Mast,Susann Luperfoy,1997-06-11 This book constitutes the strictly refereed post workshop documentation of the ECAI 96 Workshop on Dialogue Processing in Spoken Language Systems held in Budapest Hungary in August 1996 during ECAI 96 The volume presents 16 revised full papers including a detailed introduction and survey paper by the volume editors The papers are organized in sections on foundations of spoken language dialogue systems dialogue systems and prosodic aspects of spoken dialogue processing spoken dialogue systems design and implementation and evaluation of systems The book reports on work being pursued both in academia and in industry as a crucial issue in speech processing *Building Dialogue POMDPs from*

Expert Dialogues Hamidreza Chinaei,Brahim Chaib-draa,2016-02-08 This book discusses the Partially Observable Markov Decision Process POMDP framework applied in dialogue systems It presents POMDP as a formal framework to represent uncertainty explicitly while supporting automated policy solving The authors propose and implement an end to end learning approach for dialogue POMDP model components Starting from scratch they present the state the transition model the observation model and then finally the reward model from unannotated and noisy dialogues These altogether form a significant set of contributions that can potentially inspire substantial further work This concise manuscript is written in a simple language full of illustrative examples figures and tables   Increasing Naturalness and Flexibility in Spoken Dialogue Interaction Erik Marchi,Sabato Marco Siniscalchi,Sandro Cumani,Valerio Mario Salerno,Haizhou Li,2021-03-10 This book compiles and presents a synopsis on current global research efforts to push forward the state of the art in dialogue technologies including advances to language and context understanding and dialogue management as well as human robot interaction conversational agents question answering and lifelong learning for dialogue systems   **Proceedings of the European Cognitive Science Conference 2007** Stella Vosniadou,2017-09-29 This volume contains the invited lectures invited symposia symposia papers and posters presented at the 2nd European Cognitive Science Conference held in Greece in May 2007 The papers presented in this volume range from empirical psychological studies and computational models to philosophical arguments meta analyses and even to neuroscientific experimentation The quality of the work shows that the Cognitive Science Society in Europe is an exciting and vibrant one There are 210 contributions by cognitive scientists from 27 different countries including USA France UK Germany Greece Italy Belgium Japan Spain the Netherlands and Australia This book will be of interest to anyone concerned with current research in Cognitive Science   **Advances in Commercial Deployment of Spoken Dialog Systems** David Suendermann,2011-06-04 Advances in Commercial Deployment of Spoken Dialog Systems covers the peculiarities of commercial deployments of spoken dialog systems from the tools standards and design principles to build them the infrastructure to deploy them techniques to monitor evaluate and analyze them and most importantly effective strategies to adapt tune and optimize them The book shows to what extent academic spoken dialog system research converges with real world applications This academic and practical synergy can be leveraged to build successful and robust spoken dialog applications that are useful when dealing with the dynamics of the ever changing future user   **Intelligent Technologies for Interactive Entertainment** Mark Maybury,Oliviero Stock,Wolfgang Wahlster,2005-11-18 This book constitutes the refereed proceedings of the First International Conference on Intelligent Technologies for Interactive Entertainment INTETAIN 2005 held in Madonna di Campiglio Italy in November December 2005 Among the intelligent computational technologies covered are adaptive media presentations recommendation systems in media scalable crossmedia affective user interfaces intelligent speech interfaces tele presence in entertainment collaborative user models and group behavior collaborative and virtual environments cross domain user models animation and virtual

characters holographic interfaces augmented virtual and mixed reality computer graphics and multimedia pervasive multimedia creative language environments computational humour etc The 21 revised full papers and 15 short papers presented together with 12 demonstration papers were carefully reviewed and selected from a total of 39 submissions The papers cover a wide range of topics including intelligent interactive games intelligent music systems interactive cinema edutainment interactive art interactive museum guides city and tourism explorers assistants shopping assistants interactive real TV interactive social networks interactive storytelling personal diaries websites and blogs and comprehensive assisting environments for special populations impaired children elderly   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

    Spoken Multimodal Human-Computer Dialogue in Mobile Environments Wolfgang Minker,Dirk Bühler,Laila Dybkjær,2005-02-08 This book is based on publications from the ISCA Tutorial and Research Workshop on Multi Modal Dialogue in Mobile Environments held at Kloster Irsee Germany in 2002 The workshop covered various aspects of devel ment and evaluation of spoken multimodal dialogue systems and components with particular emphasis on mobile environments and discussed the state the art within this area On the development side the major aspects addressed include speech recognition dialogue management multimodal output gene tion system architectures full applications and user interface issues On the evaluation side primarily usability evaluation was addressed A number of high quality papers from the workshop were selected to form the basis of this book The volume is divided into three major parts which group together the ov all aspects covered by the workshop The selected papers have all been tended reviewed and improved after the workshop to form the backbone of the book In addition we have supplemented each of the three parts by an invited contribution intended to serve as an overview chapter   Coverbal Synchrony in Human-Machine Interaction Matej Rojc,Nick Campbell,2013-10-25 Embodied conversational agents ECA and speech based human machine interfaces can together represent more advanced and more natural human machine interaction Fusion of both topics is a challenging agenda in

research and production spheres The important goal of human machine interfaces is to provide content or functionality in the form of a dialog resembling face to face conversations All natural interfaces strive to exploit and use different communication strategies that provide additional meaning to the content whether they are human machine interfaces for controlling an application or different ECA based human machine interfaces directly simulating face to face conversation Coverbal Synchrony in Human Machine Interaction presents state of the art concepts of advanced environment independent multimodal human machine interfaces that can be used in different contexts ranging from simple multimodal web browsers for example multimodal content reader to more complex multimodal human machine interfaces for ambient intelligent environments such as supportive environments for elderly and agent guided household environments They can also be used in different computing environments from pervasive computing to desktop environments Within these concepts the contributors discuss several communication strategies used to provide different aspects of human machine interaction

The Structure of Multimodal Dialogue II M. M. Taylor,F. Néel,Don G. Bouwhuis,2000 Most dialogues are multimodal When people talk they use not only their voices but also facial expressions and other gestures and perhaps even touch When computers communicate with people they use pictures and perhaps sounds together with textual language and when people communicate with computers they are likely to use mouse gestures almost as much as words How are such multimodal dialogues constructed This is the main question addressed in this selection of papers of the second Venaco Workshop sponsored by the NATO Research Study Group RSG 10 on Automatic Speech Processing and by the European Speech Communication Association ESCA   Reinforcement Learning for Adaptive Dialogue Systems Verena Rieser,Oliver Lemon,2011-11-23 The past decade has seen a revolution in the field of spoken dialogue systems As in other areas of Computer Science and Artificial Intelligence data driven methods are now being used to drive new methodologies for system development and evaluation This book is a unique contribution to that ongoing change A new methodology for developing spoken dialogue systems is described in detail The journey starts and ends with human behaviour in interaction and explores methods for learning from the data for building simulation environments for training and testing systems and for evaluating the results The detailed material covers Spoken and Multimodal dialogue systems Wizard of Oz data collection User Simulation methods Reinforcement Learning and Evaluation methodologies The book is a research guide for students and researchers with a background in Computer Science AI or Machine Learning It navigates through a detailed case study in data driven methods for development and evaluation of spoken dialogue systems Common challenges associated with this approach are discussed and example solutions are provided This work provides insights lessons and inspiration for future research and development not only for spoken dialogue systems in particular but for data driven approaches to human machine interaction in general   Voice Communication Between Humans and Machines for the National Academy of Sciences,1994-02-01 Science fiction has long been populated with conversational computers and robots Now speech

synthesis and recognition have matured to where a wide range of real world applications from serving people with disabilities to boosting the nation s competitiveness are within our grasp Voice Communication Between Humans and Machines takes the first interdisciplinary look at what we know about voice processing where our technologies stand and what the future may hold for this fascinating field The volume integrates theoretical technical and practical views from world class experts at leading research centers around the world reporting on the scientific bases behind human machine voice communication the state of the art in computerization and progress in user friendliness It offers an up to date treatment of technological progress in key areas speech synthesis speech recognition and natural language understanding The book also explores the emergence of the voice processing industry and specific opportunities in telecommunications and other businesses in military and government operations and in assistance for the disabled It outlines as well practical issues and research questions that must be resolved if machines are to become fellow problem solvers along with humans Voice Communication Between Humans and Machines provides a comprehensive understanding of the field of voice processing for engineers researchers and business executives as well as speech and hearing specialists advocates for people with disabilities faculty and students and interested individuals *Domain-Level Reasoning for Spoken Dialogue Systems* Dirk Bühler,Wolfgang Minker,2011-04-07 Reasoning for Information Seeking and Planning Dialogues provides a logic based reasoning component for spoken language dialogue systems This component called Problem Assistant is responsible for processing constraints on a possible solution obtained from various sources namely user and the system s domain specific information The authors also present findings on the implementation of a dialogue management interface to the Problem Assistant The dialogue system supports simple mixed initiative planning interactions in the TRAINS domain which is still a relatively complex domain involving a number of logical constraints and relations forming the basis for the collaborative problem solving behavior that drives the dialogue *Emergent Trends in Robotics and Intelligent Systems* Peter Sinčák,Pitoyo Hartono,Mária Virčíková,Ján Vaščák,Rudolf Jakša,2014-10-03 What is the Role of Intelligent Technologies in the Next Generation of Robots This monograph gives answers to this question and presents emergent trends of Intelligent Systems and Robotics After an introductory chapter celebrating 70 year of publishing the McCulloch Pitts model the book consists of the 2 parts Robotics and Intelligent Systems The aim of the book is to contribute to shift conventional robotics in which the robots perform repetitive pre programmed tasks to its intelligent form where robots possess new cognitive skills with ability to learn and adapt to changing environment A main focus is on Intelligent Systems which show notable achievements in solving various problems in intelligent robotics The book presents current trends and future directions bringing together Robotics and Computational Intelligence The contributions include widespread experimental and theoretical results on intelligent robotics such as e g autonomous robotics new robotic platforms or talking robots

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