

Reasoning-based Dialog Systems

Camilo Thorne

DWS Group, Universität Mannheim, Germany
camilo@informatik.uni-mannheim.de

ESLLI 2015
Barcelona, 10.8.2015-14.8.2015



Alan Turing's Imitation Game [Tur50]



Course Structure

- **Day one:** Introduction to natural language dialog
- **Day two:** Definition and overview of dialog systems & Lab 1
- **Day three:** Chatterbots & Lab 2
- **Day four:** State-based dialog systems & Lab 3
- **Day five:** Evaluation metrics & Lab 4



Course Structure

- **Day one:** Introduction to natural language dialog
 - **Day two:** Definition and overview of dialog systems & Lab 1
 - **Day three:** Chatterbots & Lab 2
 - **Day four:** State-based dialog systems & Lab 3
 - **Day five:** Evaluation metrics & Lab 4
- ✓ **REM:** The course combines theory with a [hands-on tutorial](#) (in Java 8)



① During the labs, we will be using

- MaryTTS (text-to-speech): <http://mary.dfki.de/>
- CMU Sphinx (voice-recognition): <http://cmusphinx.sourceforge.net/>
- ALICE (chatterbot): <https://code.google.com/p/program-ab/>
- OpenDial (state-based dialog system): <http://www.opendial-toolkit.net/>

② The materials have been bundled in a (self-contained) SVN repository

- URI: <svn://svn.fmi.uni-mannheim.de/cthornef/dialog-esslli-15>

(you can check it out without entering any credentials!)



Natural Language Dialog

An Overview

Camilo Thorne

DWS Group, Universität Mannheim, Germany
camilo@informatik.uni-mannheim.de

ESLLI 2015
Barcelona, 10.8.2015-14.8.2015



- 1 Dialog in Natural Languages
- 2 Dialog States
- 3 Contextual Knowledge
- 4 Conclusions
- 5 References

Dialog Structure

user: trying chat again - Blackberry problem
rep.: Thank you for choosing to chat with IT. One moment please.
user: ok
rep.: What kind of Blackberry problem?
user: the screen is white - no graphics - battery is charged
rep.: May I please get some basic info from you for a ticket?
user: yes
rep.: What is your office phone number and working hours?
user: 704-335-4570, 8h00-18h00
rep.: SD542304 is your ticket #. The motherboard is faulty.
rep: You'll be sent a new one.
user: great, bye
rep.: Thank you for choosing to chat with us. Have a nice day.



Dialog Structure

user:	trying chat again - Blackberry problem	1
rep.:	Thank you for choosing to chat with IT. One moment please.	2
user:	ok	3
rep.:	What kind of Blackberry problem?	4
user:	the screen is white - no graphics - battery is charged	5
rep.:	May I please get some basic info from you for a ticket?	6
user:	yes	7
rep.:	What is your office phone number and working hours?	8
user:	704-335-4570, 8h00-18h00	9
rep.:	SD542304 is your ticket #. The motherboard is faulty.	10
rep:	You'll be sent a new one.	11
user:	great, bye	12
rep.:	Thank you for choosing to chat with us. Have a nice day.	13

⇒ Sequence of **turns**



Dialog Structure

user:	trying chat again - Blackberry problem	1
rep.:	Thank you for choosing to chat with IT. One moment please.	2
user:	ok	3
rep.:	What kind of Blackberry problem?	4
user:	the screen is white - no graphics - battery is charged	5
rep.:	May I please get some basic info from you for a ticket?	6
user:	yes	7
rep.:	What is your office phone number and working hours?	8
user:	704-335-4570, 8h00-18h00	9
rep.:	SD542304 is your ticket #. The motherboard is faulty.	10
rep.:	You'll be sent a new one.	11
user:	great, bye	12
rep.:	Thank you for choosing to chat with us. Have a nice day.	12

⇒ Sequence of **turns** by **user** and



Dialog Structure

user:	trying chat again - Blackberry problem	1
rep.:	Thank you for choosing to chat with IT. One moment please.	2
user:	ok	3
rep.:	What kind of Blackberry problem?	4
user:	the screen is white - no graphics - battery is charged	5
rep.:	May I please get some basic info from you for a ticket?	6
user:	yes	7
rep.:	What is your office phone number and working hours?	8
user:	704-335-4570, 8h00-18h00	9
rep.:	SD542304 is your ticket #. The motherboard is faulty.	10
rep.:	You'll be sent a new one.	11
user:	great, bye	12
rep.:	Thank you for choosing to chat with us. Have a nice day.	13

⇒ Sequence of **turns** by **user** and **system** [ABD⁺07]



Dialog Structure

user: trying chat again - **Blackberry problem**
rep.: Thank you for choosing to chat with IT. One moment please.
user: ok
rep.: What kind of Blackberry problem?
user: the screen is white - no graphics - battery is charged
rep.: May I please get some basic info from you for a ticket?
user: yes
rep.: What is your office phone number and working hours?
user: 704-335-4570, 8h00-18h00
rep.: SD542304 is your ticket #. The motherboard is faulty.
rep: You'll be sent a new one.
user: great, bye
rep.: Thank you for choosing to chat with us. Have a nice day.

⇒ Introduces **generic problem/topic**



Dialog Structure

user: trying chat again - Blackberry problem
rep.: Thank you for choosing to chat with IT. One moment please.
user: ok
rep.: What kind of Blackberry problem?
user: the screen is white - no graphics - battery is charged
rep.: May I please get some basic info from you for a ticket?
user: yes
rep.: What is your office phone number and working hours?
user: 704-335-4570, 8h00-18h00
rep.: SD542304 is your ticket #. The motherboard is faulty.
rep: You'll be sent a new one.
user: great, bye
rep.: Thank you for choosing to chat with us. Have a nice day.

⇒ Introduces the problem's **symptoms/focus** [ABD⁺07, KB10]



Dialog Structure

user: trying chat again - Blackberry problem
rep.: Thank you for choosing to chat with IT. One moment please.
user: ok
rep.: What kind of Blackberry problem?
user: the screen is white - no graphics - battery is charged
rep.: May I please get some basic info from you for a ticket?
user: yes
rep.: What is your office phone number and working hours?
user: 704-335-4570, 8h00-18h00
rep.: SD542304 is your ticket #. The **motherboard** is faulty.
rep: You'll be sent a new one.
user: great, bye
rep.: Thank you for choosing to chat with us. Have a nice day.

⇒ Determines the **specific problem** [ABD⁺07]



Dialog Structure

user: trying chat again - Blackberry problem	}	greet
rep.: Thank you for choosing to chat with IT. One moment please.		
user: ok	}	request
rep.: What kind of Blackberry problem?		
user: the screen is white - no graphics - battery is charged	}	ground
rep.: May I please get some basic info from you for a ticket?		
user: yes	}	state
rep.: What is your office phone number and working hours?		
user: 704-335-4570, 8h00-18h00	}	greet
rep.: SD542304 is your ticket #. The motherboard is faulty.		
rep: You'll be sent a new one.		
user: great, bye		
rep.: Thank you for choosing to chat with us. Have a nice day.		

⇒ Turns fulfill **dialog acts** (DAs) & **units** (DUs) [ABD⁺07, SCB⁺00]



Dialog Structure

user: trying chat again - Blackberry problem	}	greet
rep.: Thank you for choosing to chat with IT. One moment please.		
user: ok	}	request
rep.: What kind of Blackberry problem?		
user: the screen is white - no graphics - battery is charged	}	ground
rep.: May I please get some basic info from you for a ticket?		
user: yes	}	state
rep.: What is your office phone number and working hours?		
user: 704-335-4570, 8h00-18h00	}	greet
rep.: SD542304 is your ticket #. The motherboard is faulty.		
rep: You'll be sent a new one.		
user: great, bye		
rep.: Thank you for choosing to chat with us. Have a nice day.		

⇒ Dialog proceeds under the **initiative** of dialog participants



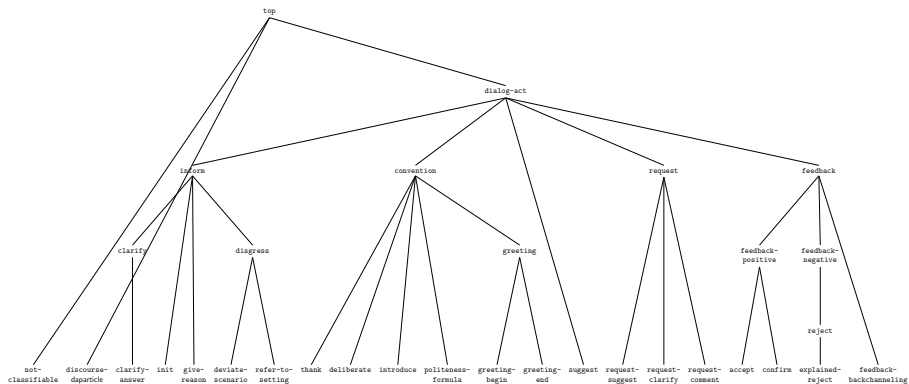
Dialog Structure

user: trying chat again - Blackberry problem	}	greet
rep.: Thank you for choosing to chat with IT. One moment please.		
user: ok	}	request
rep.: What kind of Blackberry problem?		
user: the screen is white - no graphics - battery is charged	}	ground
rep.: May I please get some basic info from you for a ticket?		
user: yes	}	state
rep.: What is your office phone number and working hours?		
user: 704-335-4570, 8h00-18h00	}	greet
rep.: SD542304 is your ticket #. The motherboard is faulty.		
rep: You'll be sent a new one.		
user: great, bye		
rep.: Thank you for choosing to chat with us. Have a nice day.		

⇒ Turns are short and may involve ellipsis and/or dis-fluencies



VERBMOBIL Dialog Act Taxonomy [ABWF⁺97].



Dialog Act Distribution [SCB⁺00]

Switchboard DA	VERBMOBIL DA	rel. freq.
statement	statement	0.36
backchannel	feedback	0.19
opinion	inform	0.13
uninterpretable	not-classifiable	0.06
agreement	feedback	0.05
appreciation	convention	0.02
Y/N-question	request	0.02

Top 7 dialog acts of the Switchboard corpus [SCB⁺00]



Dialog Act Distribution [RT09] (ctd.)

Damsl TRAINS	Damsl Monroe	SWBD-Damsl Switchboard	HCRC HCRC Maptask	HCRC DCIEM Maptask	Verbmobil II Verbmobil English	Verbmobil II Verbmobil German	Verbmobil I Verbmobil I German
statement 45.9	51.4	49	explain 7.9	7.9	Inform,... 22.8	21.2	12.2
info-request 15.2	9.9	questions 4.9	query,check,align 23.5	20.3			
action-dir,oo 12.2	12.9	0.7	instruct 15.6	15.2	request,suggest 26.0	27.0	32
commit,offer 23.8	16.8	0.1			commit 0.5	0.8	
conventional 2.5	0.6	1.4			13.4	15.6	16.5
answer 14.7	8.4	3	reply,clarify 22.8	20	feedback 15.2	9.8	0.6
accept 30.0	23.0	5			accept,confirm 10.3	12.3	13.5
reject 2.2	0.5	0.2			reject,explained 3.3	4.4	8.2
other agree 3.6	1.8	0.3			clarify 2.3	1.9	8.9
Understanding 30.2	28.5	23	acknowledge 20.5	28.1	backchannel 3.6	3.3	
non-understand 1.2	0.5	0.1					



Dimensions of Dialog

- ① Phonetics & intonation
- ② Morphology: tokenization, stemming, word-segmentation
- ③ Morphosyntax: part-of-speech (POS) annotation
- ④ Syntax: phrase structure and/or dependency structure
- ⑤ Discourse: discourse structure



Dimensions of Dialog

- ① Phonetics & intonation
- ② Morphology: tokenization, stemming, word-segmentation
- ③ Morphosyntax: part-of-speech (POS) annotation
- ④ Syntax: phrase structure and/or dependency structure
- ⑤ Discourse: discourse structure

- ⑥ **Semantics:**
 - lexical meaning, word-sense disambiguation
 - phrasal meaning
 - co-reference resolution
 - **topic** and **focus** identification \Rightarrow **dialog state**



Dimensions of Dialog

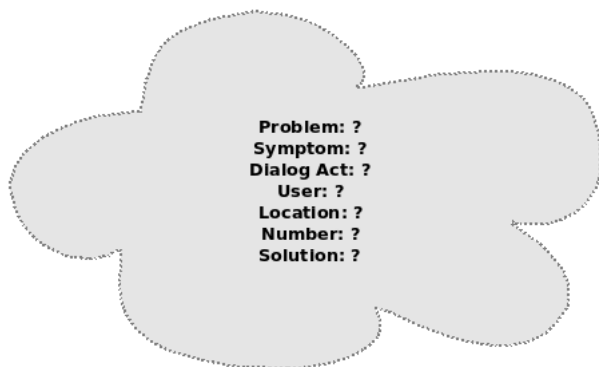
- ① Fonetics & intonation
- ② Morphology: tokenization, stemming, word-segmentation
- ③ Morphosyntax: part-of-speech (POS) annotation
- ④ Syntax: phrase structure and/or dependency structure
- ⑤ Discourse: discourse structure

- ⑥ Semantics:
 - lexical meaning, word-sense disambiguation
 - phrasal meaning
 - co-reference resolution
 - topic and focus identification ⇒ dialog state

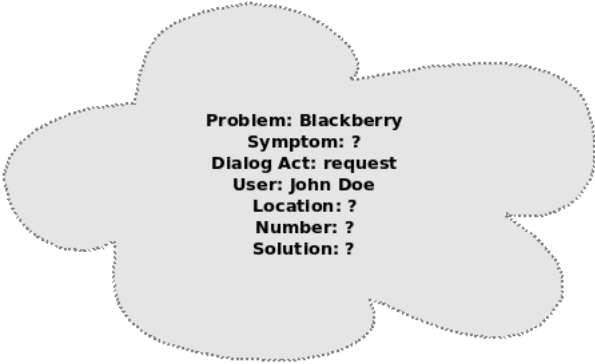
- ⑦ Pragmatics:
 - intention of speaker ⇒ dialog act
 - context ⇒ grounding and implicature



Dialog State - Frames [GMM00]

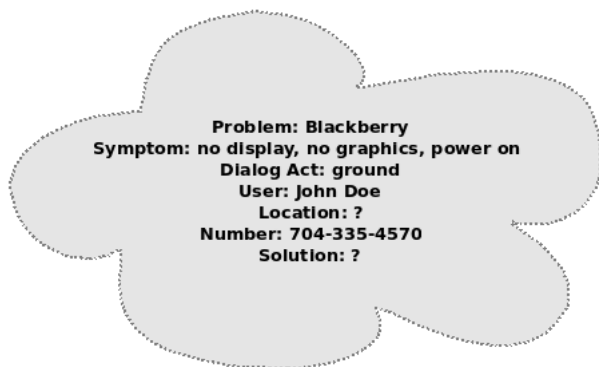


⇒ At the beginning, the frame/state is empty ([greet](#))




Problem: Blackberry
Symptom: ?
Dialog Act: request
User: John Doe
Location: ?
Number: ?
Solution: ?

⇒ The user request induces a candidate problem ([request](#))




⇒ A conversation is engaged to gather more information (**ground**)




Problem: Blackberry motherboard
Symptom: no display, no graphics, power on
Dialog Act: ground
User: John Doe
Location: 2nd floor, office 202, desk 5
Number: 704-335-4570
Solution: ?

⇒ We continue until we fill the frame (**ground**)



Problem: Blackberry motherboard
Symptom: no display, no graphics, power on
Dialog Act: state
User: John Doe
Location: 2nd floor, office 202, desk 5
Number: 704-335-4570
Solution: replace

⇒ A solution is determined and the dialog ends (**state** + **greet**)



Problem: Blackberry motherboard
Symptom: no display, no graphics, power on
Dialog Act: state
User: John Doe
Location: 2nd floor, office 202, desk 5
Number: 704-335-4570
Solution: replace

We exploited information **implicit in the dialog context!**



- An important part of a dialog consists in
 - ① clarifying its subject matter ⇒ **topic** elicitation
 - ② discussing some aspects of it ⇒ **focus** elicitation
- Such process will continue until a **common ground** is reached
- This kind of “iterative refinement” in dialog is known as **grounding**
- Grounding may involve the use of implicit background knowledge
⇒ **dialog context**

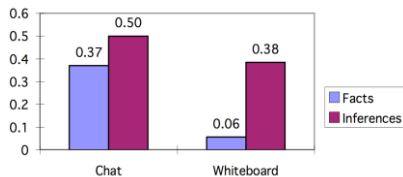


Grounding Act Distribution [RT09]

grounding acts

Label	Description
initiate	Begin new DU, content separate from previous uncompleted DUs
continue	same agent adds related content to open DU
acknowledge	Demonstrate or claim understanding of previous material by other agent
repair	Correct (potential) misunderstanding of DU content
Request Repair	Signal lack of understanding
Request Ack	Signal for other to acknowledge
cancel	Stop work on DU, leaving it ungrounded and ungroundable

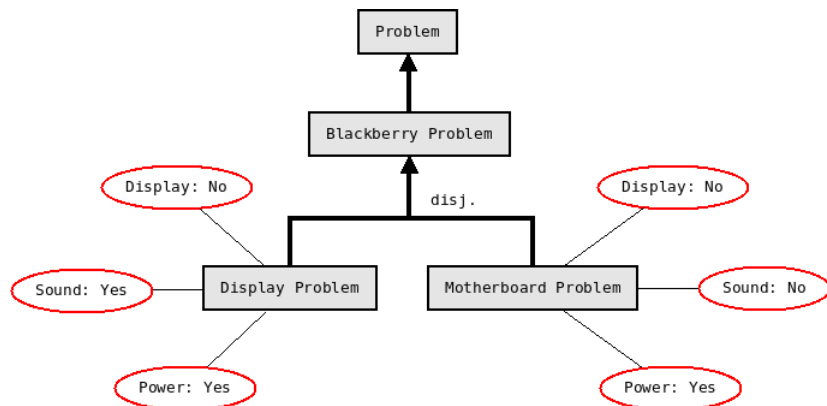
grounding by corpus



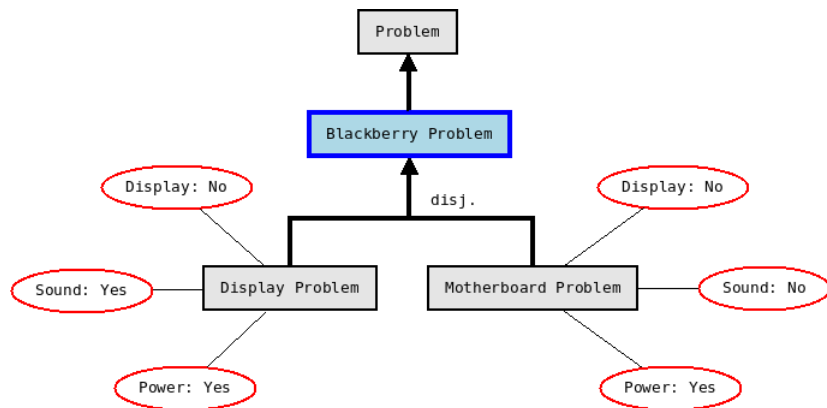
⇒ in both corpora the distribution is skewed towards repairs

⇒ conflicts resolved by reasoning over context (background knowledge & implicatures)

Context - Blackberry World [QDR09]

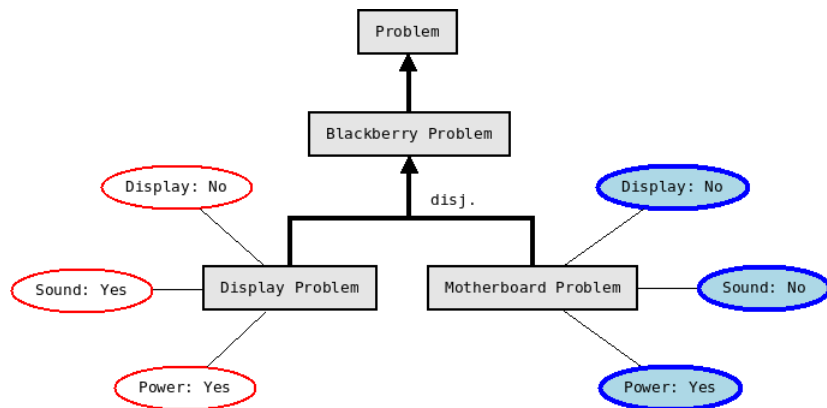


Context - Blackberry World [QDR09]



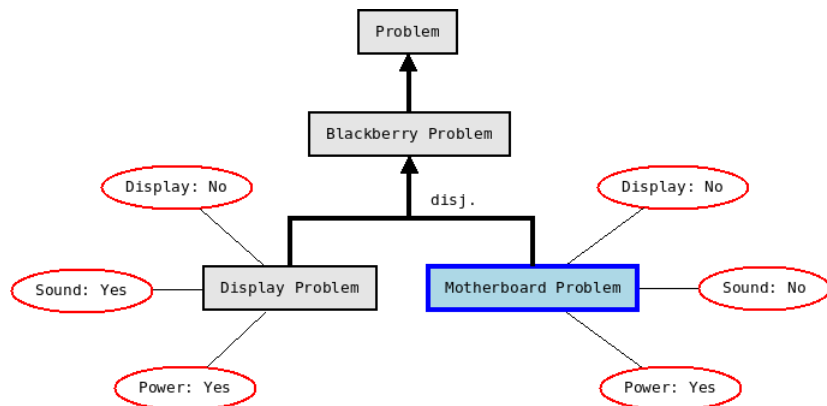
⇒ dialog topic

Context - Blackberry World [QDR09]



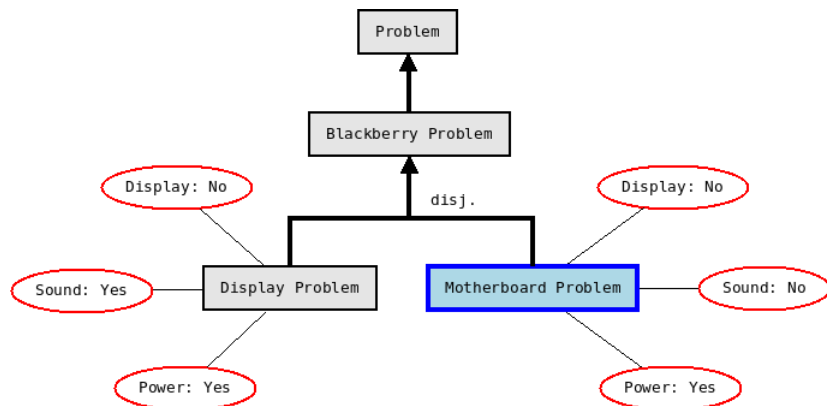
⇒ dialog focus

Context - Blackberry World [QDR09]



⇒ refine to **intended** topic via focus

Context - Blackberry World [QDR09]



Ground the dialog by logically reasoning over the ontology!



Centering, Saliency and Cohesion [Mit02]

- Dialogs refer to dialog **centers**, expressed by phrasal chunks (noun phrases)
- Provide **cohesion** to dialog anchoring conversations around topics

- Each dialog turn i gives rise to
 - ① a set C_i of centers
 - ② a set $F_i \subseteq C_i$ of forward-looking centers (focus)
 - ③ a backward-looking center $T_i \in F_i$ of i (topic)

- Partially ordered in i ordered by **saliency** \leq_s : given two centers c and c' from i , $c \leq_s c'$ iff
 - ① c is the subject of i , or
 - ② c' is the direct object of i , or
 - ③ c' is the indirect object of i , or
 - ④ c' is a center of $i - 1$ (within each DU)

- Turn i 's topic is T_i : **the most salient center** of turn $i - 1$.
- Anaphors: a new center is added if coreferences have been solved



Conclusions

- ① Provided an overview of dialog structure in natural language (English)
- ② Dialog structure must address the semantic, pragmatic and dynamic dimensions of dialog
- ③ Stressed the importance of (dynamic) dialog states or frames
⇒ dialog grounding
- ④ Stressed the importance of exploiting background knowledge
⇒ dialog context
- ⑤ Dialog systems need to appropriately process such dialog features





Thank You!!!

References I



Kate Acomb, Jonathan Bloom, Krishna Dayanidhi, Phillip Hunter, Peter Krogh, Esther Levin, and Roberto Pieraccini.

Technical support dialog systems: Issues, problems and solutions.

In Proceedings of the Workshop on Bridging the Gap: Academic and Industrial Research in Dialog Technologies, 2007.



Jan Alexandersson, Bianka Buschbeck-Wolf, Tsutomu Fujinami, Elisabeth Maier, Norbert Reithinger, Birte Schmitz, and Melanie Siegel.

Dialogue acts in VERBMOBIL-2.

Technical report, DFKI Saarbrücken, 1997.



Dafydd Gibbon, Inge Mertins, and Roger K. Moore, editors.

Handbook of Multimodal and Spoken Dialogue Systems: Resources, Terminology, and Product Evaluation.

Springer, 2000.



References II



Manuel Kirschner and Raffaella Bernardi.

Towards an empirically motivated typology of follow-up questions: The role of dialogue context.

In *Proceedings of SIGDIAL 2010*, 2010.



Ruslan Mitkov.

Anaphora Resolution.

Pearson Education, 2002.



Silvia Quarteroni, Marco Dinarelli, and Giuseppe Riccardi.

Ontology-based grounding of spoken language understanding.

In *Proceedings of ASRU 2009*, 2009.



Antonio Roque and David Traum.

Improving a virtual human using a model of degrees of grounding.

In *Proceedings of the 21st International Joint Conference on Artificial Intelligence (IJCAI 2009)*, 2009.





Andreas Stolcke, Noah Coccaro, Rebecca Bates, Paul Taylor, Carol Van Ess-Dykema, Klaus Ries, Elizabeth Shriberg, Daniel Jurafsky, and Rachel Martin. Dialogue act modeling for automatic tagging and recognition of conversational agents.

Computational Linguistics, 26(6):339–373, 2000.



Alan Turing.
Computing machinery and intelligence.

Mind, 59:433–460, 1950.

Appendix - Switchboard Corpus DAs I

DA	tag	example	count
Statement-non-opinion	sd	Me, I'm in the legal department.	75145
Acknowledge (Backchannel)	b	Uh-huh.	38298
Statement-opinion	sv	I think it's great	26428
Agree/Accept	aa	That's exactly it.	11133
Abandoned or Turn-Exit	%	So, -	10569
Appreciation	ba	I can imagine.	4765
Yes-No-Question	qy	Do you have to have any special training?	4727
Non-verbal	x	[Laughter], [Throat_clearing]	3630
Yes answers	ny	Yes.	3034
Conventional-closing	fc	Well, it's been nice talking to you.	2582
Uninterpretable	%	But, uh, yeah	15550
Wh-Question	qw	Well, how old are you?	1979
No answers	nn	No.	1377
Response Acknowledgement	bk	Oh, okay.	1306
Hedge	h	I don't know if I'm making any sense or not.	1226
Declarative Yes-No-Question	qy^d	So you can afford to get a house?	1219
Other	fo_o_fw_by_bc	Well give me a break, you know.	883
Backchannel (question form)	bh	Is that right?	1053
Quotation	^q	You can't be pregnant and have cats	983
Summarize/reformulate	bf	Oh, you mean you switched schools for the kids.	952
Affirmative non-yes answers	na	It is.	847



Appendix - Switchboard Corpus DAs II

DA	tag	example	count
Action-directive	ad	Why don't you go first	746
Collaborative Completion	^ 2	Who aren't contributing.	723
Repeat-phrase	b^ m	Oh, fajitas	688
Open-Question	qo	How about you?	656
Rhetorical-Questions	qh	Who would steal a newspaper?	575
Hold before answer/agreement	^ h	I'm drawing a blank.	556
Reject	ar	Well, no	346
Negative non-no answers	ng	Uh, not a whole lot.	302
Signal-non-understanding	br	Excuse me?	298
Other answers	no	I don't know	286
Conventional-opening	fp	How are you?	225
Or-Clause	qrr	or is it more of a company?	209
Dispreferred answers	arp_nd	Well, not so much that.	207
3rd-party-talk	t3	My goodness, Diane, get down from there.	117
Offers, Options, Commits	oo_co_cc	I'll have to check that out	110
Self-talk	t1	What's the word I'm looking for	103
Downplayer	bd	That's all right.	103
Maybe/Accept-part	aap_am	Something like that	105
Tag-Question	^ g	Right?	92
Declarative Wh-Question	qw^ d	You are what kind of buff?	80
Apology	fa	I'm sorry.	79
Thanking	ft	Hey thanks a lot	78



Appendix - Switchboard Corpus Sample

DA	DU	turn #	turn
b	A.13	utt1:	Yeah. /
qy	A.13	utt2:	[Do, + would] you prefer all trials by a judge? /
nn	B.14	utt1:	No, /
sv ^e	B.14	utt2:	I think there are certain things that, F uh, the jury can determine as far as, F uh, guilty or not guilty, /
sv	B.14	utt3:	C but as far as the [[af-, + af-,] + affixing] of punishment and fines and things of that nature, ithroat_clearing _i I don't know if that is best left up to the jury [to de-, + to award,] D you know. /
sv	B.14	utt4:	Two point two million dollar kind of settlement versus a judge knowing, D you know, it's true that, D you know, this may be sad and all that thing, /
sv	B.14	utt5:	C but, F uh, the jury I think is best, in most cases, suited for determination of guilt and innocence, but not the award [of, + of] penalties and fines and punishment. /
aa	A.15	utt1:	Yeah, /
aa	A.15	utt2:	I would agree with that. /
sv	A.15	utt3:	I think you're righ-, /
sv	A.15	utt4:	I think they sometimes get carried away by the circumstances and make huge settlements thinking D well it's only going to cost the insurance company, /
%	A.15	utt5:	C and, -/

