Reciprocal Learning via Dialogue Interaction: Challenges and Prospects

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Introduction

- Talk about natural language
- Reseach on conversational agents / dialogue systems (for practical purposes but also as cognitive models)
- Language as a vehicle for learning - tasks / skills / ...
  $\longrightarrow$ informational coordination
- But learning by talking also involves language coordination
  - learning about language itself – about which words we use to talk about a domain and what we mean by them.
  - this is a case of reciprocal learning – a process whereby interacting agents learn to communicate with each other.
- Language coordination is a fundamental fetaure of human communication
- We'd like to endow conversational agents with the capability of language learning

Overview

Main claims:

- humans learn through language and about language in dialogue interaction; language coordination is a form of reciprocal learning
- state-of-the-art dialogue systems do not use learning methods appropriate for language coordination (they are data intensive and not interactive)
- a bottleneck is the lack of a formal semantic theory of language coordination, which should be coupled with the right machine learning techniques.

Outline of the talk:

- overview of empirical findings related to language coordination
- overview of current approaches to conversational agents that attempt to integrate aspects of language coordination
- challenges of reciprocal learning for language coordination in human-machine interaction

Coordination and Learning in Dialogue

There is ample evidence from psychology and cognitive science showing that dialogue participants tend to adapt to each other:

- they rapidly converge on the same vocabulary
- tend to use similar syntactic structures
- adapt their pronunciation and speech rate to one another
- mimic their interlocutor's gestures

Human users of artificial dialogue systems also adapt their language to the system:

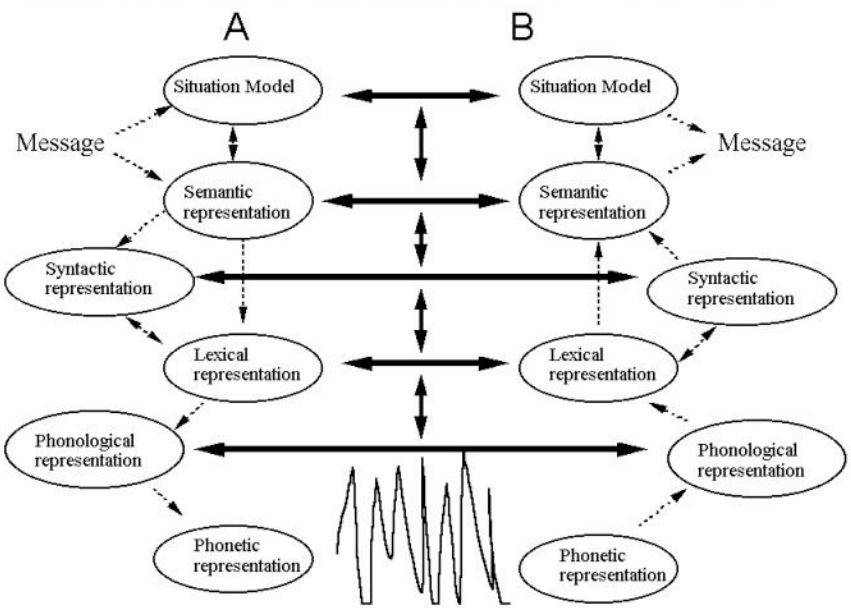
- human users tend to align with the syntactic structures and the vocabulary used by a computer
- children adapt the amplitude of their speech to that of spoken animated dialogue agents

Implicit Alignment

What explains such ubiquitous adaptation? One possible answer:

Interactive Alignment Model (Pickering & Garrod 2004)

- alignment is an automatic adaptation process, driven by implicit priming mechanisms
- linguistic representations become aligned at many levels (phonological, lexical, syntactic); this leads to coordination at the conceptual/semantic level



Computational Modelling of Implicit Alignment

- use of several measures to quantify the degree of alignment between dialogue participants in dialogue corpora
- use of cognitive modelling techniques to reproduce it
- human-human tutoring dialogue: some alignment measures are useful predictors of learning

Explicit Coordination

Another possible answer: Collaborative Model (Clark and colleagues)

- dialogue is a form of joint action: speakers and hearers take into account each other's communicative needs
- they use explicit collaborative strategies: feedback, clarification questions, partner-specific "conceptual pacts"

A: ?*$!@#
B: Pardon? $\rightsquigarrow$ *were you talking to me? / wa did you say?*

A: I got tickets for the opera.
B: Where for? $\rightsquigarrow$ *where did you say you got tickets for?*

A: He's going with Sharon.
B: His girlfriend? $\rightsquigarrow$ *by Sharon, do you mean his girlfriend?*

A: How old are you?
B: Why? $\rightsquigarrow$ *why are you asking this now?*

Explicit Coordination and Language Acquisition

First language acquisition: not only exposure to data, but it crucially relies on feedback given in interaction.

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A: I'm trying to tip this over, can you tip it over? Can you tip it over?
B: Okay I'll turn it over for you.

Abe: That's a nice bear.
Mother: Yes, it's a nice panda.

Naomi:   mittens.
Father:  gloves.
Naomi:   gloves.
Father:  when they have fingers in them they are called gloves and when
         the fingers are all put together they are called mittens.
```

Language acquisition is a special case of language coordination where there is a clear asymmetry between agents' expertise

Adults encounter similar situations and use similar mechanisms for semantic coordination

Language Coordination

Competent adult speakers may have non-identical linguistic resources, and these can change during a dialogue.

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A: A docksider.
B: A what?
A: Um.
B: Is that a kind of dog?
A: No, it's a kind of um leather shoe, kinda
pennyloafer.
B: Okay, okay, got it.

⇒ Thereafter "the pennyloafer"
```

The learning that results from the process of semantic coordination

- may be limited to a specific dialogue or a specific partner;
- it may become part of our long-term knowledge; or
- it may spread over a community and eventually become part of *the* language as it is represented in dictionaries.

Interim Summary

There is ample evidence that humans (adults and children) engage in language coordination in dialogue.

- Human linguistic resources are flexible and dynamic - can be modified at all levels of linguistic processing during interaction
- The behaviours used to adapt linguistic resources are varied:
  - implicit mechanisms to align external features of their language
  - explicit collaborative strategies that lead to shared knowledge
- We learn incrementally, with few exposures to data
- The effects of learning can have different scope:
  - one dialogue / partner
  - individual long-term knowledge
  - linguistic community

Related Approaches: Dialogue Systems

Several recent systems adapt the system's surface linguistic form to the individualities of a user.

- Sentence structure with over-generation and rank approach:
  - generation of large set of alternative sentences and filtering according to individual preferences
  - off-line learning from large training data set.
- Lexical alignment with Reinforcement Learning:
  - predefined set of synonym terms (*broadband modem* vs. *red box*)
  - estimates expertise of unknown users as the dialogue progresses and adapts its terminology
- Style adaptation:
  - predefined set of linguistic styles
  - adapt to the level of formality and politeness of the user's utterances
- Gesture adaptation

Related Approaches: Dialogue Systems

Several recent systems adapt the system's surface linguistic form to the individualities of a user.

However. . .

- only surface adaptation
- predifined sets of alternatives
- large amounts of data required for training

- no learning at the level of linguistic resources
- no true incremental, interactive learning

Related Approaches: Multiagent Systems

Multiagent system simulations of reciprocal learning for communication avoid some of these problems

- Iterative learning / language games
  - category formation and emergent vocabularies
  - grounded language acquisition and language evolution
- Semantic web
  - ontologies matching / negotiation

This line of research is very promissing: learning agents that can coordinate on form and meaning of communication systems.

However. . .

- focuses on formal / synthetic language coordination
- far away from agents that can use natural language to coordinate with humans and learn from them.

Towards Reciprocal Learning

One key element missing: a detailed linguistic theory of natural language dynamics

- research within computational linguistics has not yet paid much attention to the dynamics of language itself:
  - language is considered a static entity that does not change during the course of a dialogue.
- need to reorienting the focus of theories of natural language semantics to get a deeper understanding of coordination processes that can underpin the development of learning conversational agents.

We are currently working on this front

- Information State Update approach to dialogue management
- dialogue moves related to semantic coordination (such as corrective feedback) bring about updates to linguistic resources

Suitable Learning Algorithms

The foundational linguistic work needs to be coupled with suitable machine learning techniques.

Constraints on suitable learning algorithms:

- learning algorithms for language coordination should be highly incremental, allowing for rapid learning from single (or very few) exposures to data;
- they should be reciprocal and interactive, being compatible with both explicit and implicit dialogue strategies.
- they need to be able to operate on fine-grained linguistic representations, to afford semantic learning and not only external adaptation

Current approaches to learning in conversational agents do not meet all the above requirements.

Conclusions

- We have presented the main ideas behind the challenge of reciprocal learning for language coordination.
- Language coordination is pervasive in natural language communication – critical for achieving overall coordination.
- A key way to move forward, we claim, is to make progress on
  - the development of formal theories of language dynamics
  - the combination of insights from these theories and suitable machine learning techniques for reciprocal, incremental, and interactive learning.
- Many interesting learning techniques that could be appropriate are being explored in this community, e.g., one-shot learning, bootstrap learning, active learning, ...
- Can they be adpated to the intricacies of natural language?