Human-computer dialogue with Game Theory...?
Overview of the presentation ...
The domain: natural language
Our goals here are:

- Introduce some key terminology
- Hint at the complexities of the phenomenon
- Begin hinting at some potential applications for game theory

An outline of this section
Some basic terminology

- Sentence vs utterance
- The descriptive (constative) fallacy
- Propositional content vs pragmatic meaning
- Illocutionary force
  - Perlocutionary force
  - Illocutionary force
Truth-conditional semantics

Ex.: Let $S = \text{\"Letizia de Ramolino was the mother of Napoleon\"}$.

How can we capture the propositional content $P$ of $S$?

Let $W = \{\text{all possible worlds}\}$, $B = \{\text{True, False}\}$.

Then let $P(S) = f : W \rightarrow B$. 

Truth-conditional semantics
Truth-conditional semantics — Pt II

- Compositionality (and, or, because, etc.)
- Universality

This leads to certain expectations

Ex.: Let $S = \text{"Letizia de Ramolino was the mother of } \text{Napoleon".}$
Are there patterns here?

- "This sentence is false." ●
- If a sentence is neither true nor false, is it nonsense?
- "I am the mother of Napoleon." ●

Is every sentence true or false? Examples?

Performativity speech (Introduction)
Are there utterances such that:

1. They do not describe, constate, or report;
2. They are neither true nor false;
3. Their uttering is, or is a part of, the doing of an action which would not normally be described as “just saying”;
4. They are not nonsense?

Performativeness — Pt II
There are.

- "I christen this ship the HMS Barham."
- "I promise to be there tomorrow."
- "I advise you not to come."
- "I hereby declare this meeting adjourned."
- "Take thee [..] to be my wedded wife."
- "I christen this ship the HMS Barham."

Performative speech – Pt III
Performative speech – Pt III (example)

Ex.: “I christen this ship the HMS Barham,” as uttered when smashing a bottle against the ship’s stem.
Performative speech — Pt III (example)

Ex.: "I christen this ship the HMS Barham," as uttered when smashing a bottle against the ship’s stem.

... nor anything I did do or will do in the future

... saying

Is not reporting what I would be said to be doing in so saying

Does not describe, constate, report

smashing a bottle against the ship’s stem...
Performative speech — Pt III (example)

Ex.: “I christen this ship the HMS Barham,” as uttered when smashing a bottle against the ship’s stem.

To name a ship is precisely to say “I christen this ship,”

… nor anything I did do or will do in the future

• saying

• Does not describe, constate, report

• Is not reporting what I would be said to be doing in so

smashing a bottle against the ship’s stem
Ex: “I christen this ship the HMS Barham,” as uttered when smashing a bottle against the ship’s stem.

Unless you’re an early 20th century positivist philosopher of language, it is not nonsense.
Performative speech – Pt IV

...These are also known in some communities as ...

Contrast with previous positivist view (Russell et al.)

Origins with J. L. Austin (1940’s/50’s)

A lot of theory here across several literatures

Explicit and implicit speech acts
Performative speech – Pt IV

Dialogue acts

These are also known in some communities as...

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Explicit and implicit speech acts
Performative speech — Pt V

- Performative utterances are neither true nor false
- But they can "fail"

- We've mentioned they "go through" under proper circumstances
- What are those circumstances?
Performative speech — Pt V

Felicity conditions

● Misapplications
  ○ Convention existence
  ○ Convention appropriateness

● Misexecutions
  ○ Incorrect execution
  ○ Incomplete execution
  ○ Inverse correctness (Misexecutions)

appropriateness
Convention
Convention existence
(Misexecutions)

Felicity conditions
Performative speech — Pt VI

So far, all our examples have been of the form "I X", where X is the name of the action I perform (asking, naming, warning, betting, etc.).

But we don't typically speak this way.

○ "I [hereby] request that you close the door.

For example:

"I hereby request that you close the door."
Performative speech — Pt VI (continued)

Ex.: “I hereby request that you close the door.”

“I want you to close the door.”
“Would you mind closing the door?”
“Hadn’t you better close the door?”
“Would you mind awfully if I were to ask you to close the door?”
Performative speech — Pt VI (continued)

Ex.: “I [hereby] request that you close the door.”

- “I am sorry to have to tell you to close the door.”
- “Did you forget the door?”
- “How about a bit less breeze in here?”
- “Now Johnny, what do big people do when they come in?”
- “Johnny, what am I going to say next?”
- “Johnny, what do I always tell you?”
- “Brr.”

[445x751]Performative speech — Pt VI (continued)
We have an ability to infer the intentions of others

- We act cooperatively
- And we assume cooperation
- We act cooperatively
- We have an ability to infer the intentions of others

This intuition has been formalized as follows...

... classical semantics leads to apparent arbitrariness of the signal (vis-a-vis...
Recognizing that intention (i)

\[ \text{\textit{i}. S intended } \text{to be achieved simply by } H \]

\[ \text{\textit{ii}. S intended } \text{to cause effect } z \text{ in recipient } H \]

\[ \text{\textit{z meaning-\textit{nn} by uttering } u \text{ iff: } S \text{ meant-\textit{nn} by uttering } u \text{ itt: meaning-\textit{nn}} \text{ Skip non-natural meaning, or meaning-\textit{nn}} \]

Performance speech – Pt VII (continued)
Performative speech — Pt VII (continued)

Gricean non-natural meaning, or meaning

Speaker (utterer) meaning vs timeless (conventional)

Recognizing that intention (i)

\[ \text{S intended (i) to be achieved simply by H} \]

\[ \text{H \text{intended (i) to cause effect in recipient}} \]

\[ \text{if S meant-\text{nn} by uttering U \iff} \]

Griccean non-natural meaning, or meaning

(continued)
There are schemes for annotating dialogue acts.

- TRAINS corpus annotations
- DAMSL
- DAMSL
- ISO 24617-2 Standard (DiAML)

Communicative functions (inform, agree, answer, confirm, offer, accept-offer, decline-offer, etc.)

Dimensions (allo-feedback, time management, turn management)
How these might lead to a natural game theoretic interpretation of dialogue?
There are other context-dependent, non-truth conditional, defeasible pragmatic inferences:

- Politeness
- (Conceptual) Metaphor
- (Pragmatic) Presupposition
- (Pragmatic) Implicature
- (Conceptual) Metaphor
- Indexicality/deixis

Coming up: Reasoning from context
But just how large a role does it play?

This seems intuitive to those of us without theoretical biases. But just how large a role does it play?

Context can play a role in interpretation of NL utterances.

○ Interpreted as 'command', 'close door' in the appropriate context(s)

○ "What am I about to say, Johnny?"

Deixis – Pt I (Introduction)
What happens when information is missing?

Deixis — Pt I (example 1)

What happens when information is missing?

Deixis — Pt I (example 1)
What happens when information is missing?

Deixis — Pt I (example ii)
What happens when information is missing?

- You find a bottle washed up on the beach; inside is a message which reads:
  - “Meet me here a week from now with a stick about this big.”
What happens when information is missing?

You turn on the TV just in time to hear an interviewee say:

“...But I fundamentally disagree with that.”

to a TV journalist.

Deixis — Pt I (example iv)
Deixis — Pt II (background cont’d)

These underspecified, inherently ambiguous words and expressions are called deictic expressions (indexicals). Like these posed problems for early truth-conditional semantics, deictic expressions are called deictic. These underspecified, inherently ambiguous words and expressions cannot be reduced to a single one. Can this final pragmatic residue be translated out into a context-free metalanguage?
Deixis — Pt II (background cont’d)

Deictic expressions evaluated according to context, which consists in a set of deictic coordinates, and

- Now add dimensions for the participant and social roles, and
  
  - These circles shift constantly (inferred on the fly)
  - Temporal, social proximity

- Now imagine concentric circles — discrete zones of spatial, temporal, social, and participant dimensions plus time

- Imagine a 4D space — 3 spatial dimensions plus time

Speaker at the center (deictic centre)

Deictic expressions evaluated according to context.
Now our context is a 7-dimensional space centered at the speaker and addressee switch participant-roles, theorem context shifts to be the addressee. The meanings of all deictic expressions shifts accordingly.

Deixis – Pt II (background cont’d)
The speaker can also elect to project the deictic centre to another participant (empathy). This is complicated (children struggle to master it).
Recall now the five deictic axes:

- Person (participant) deixis
- Place deixis
- Time deixis
- Social deixis
- Discourse deixis
Deixis — Pt II (person example)

Roles: speaker, addressee, audience (and many others)

- "I am Letizia de Ramolino."
- "Do you know the Muffin Man?"
- "Someone is hangry, isn’t he?"
- "Yes, Samuel Barham is speaking."
- "Can Billie have some ice-cream, Daddy?"

- "Yes, Samuel Barham is speaking."
- "Can Billie have some ice-cream, Daddy?"
Deixis — Pt II (time example)

Distinguish: times and time spans wrt coding time (CT) and receiving time (RT)

● “Don’t shoot now, shoot now and now.”
● “The match is on Thursday.”
● “I’ll see you tomorrow.”
Deixis — Pt II (place example)

Distinguish:
- **proximity** (proximal, distal), location

- *Place it here.*
- *Give that one to me, and I'll give you this one.*
- *He's coming vs. I'm coming.*
- *When I'm in the office, you can come to see me.*
- *I came over several times to visit you, but you were never there.*
Deixis — Pt II (discourse example)

Distinguish:

- token mentions, inferred propositions, inferred intentions or actions, etc.

- "I'm just not that kind of person." — "That's a lie."
- "I've never seen him before." — "That's true."
- "Don't say that, Johnny." — "*%&#!"
- "What's that? Spell it." — "Rhinoceros."

Very noble of you."
Deixis — Pt II (social example)

Distinguish:

[Japanese pronoun/verb/adjective system]

-The taboo vocabulary (Dyalnyuy) in Dyirbal
-

- "parlez-vous français?"
- "I disagree, Your Honor.

-Distinguish: social, hierarchical, familial rank or position

-
Deixis — Pt III

● Are the conventional words and phrases we've been considering alone in being deictic?

○ i.e., their reference is inferred in a deictic coordinate system

● Perhaps all (or most) of language is in some sense contextually dependent on being deictic?

Deixis — Pt III
Consider the sentence: “That [points to man drinking Vulcan tea across the room] is Lieutenant Tuvok.”

**Gestural deixis**

Vulcan tea across the room]] is Lieutenant Tuvok.

Consider the sentence: “That [points to man drinking (continued)]

Deixis – Pt III (continued)
Deixis — Pt III (continued)

● How about: "That man over there drinking Vulcan tea is Lieutenant Tuvok."

○ non-gestural deixis
non-gestural deixis

How about: "That man over there drinking Vulcan tea is Lieutenant Tuvok."

Deixis — Pt III (continued)
Deixis — Pt III (continued)

The is ambiguous between deictic axes along the is ambiguous between deictic axes

along deictic axes which deictic dimension to search

‘The man drinking Vulcan tea over there’ is ambiguous between deictic axes

Still asking the addressee to search the contextual space for a referent

How about: ‘The man drinking Vulcan tea over there’ is

Deixis — Pt III (continued)
Deixis — Pt IV

- Interpretation of deictic expressions relies on a running discourse context.
  - Conversational context or common ground
  - Referents come “pre-loaded” or are grounded during discourse

Referents come “pre-loaded” or are grounded during discourse. Common-sense knowledge, acculturation, etc.

- Salience, feedback channels, etc.

Interpretation of deictic expressions relies on a running discourse context.

Deixis — Pt IV
Deixis — Conclusion (frames)

But NB:

the can also refer to discourse referents that have not yet been grounded.

Lexemes are understood in relation to a semantic frame.

- E.g. "sell" -> [buyer, goods, money, seller, the various relations between these]  

- Frame semantics (Fillmore, 1982 multiaque sequentiæ)

This (and other linguistic issues) has been explained by

Frame semantics (Fillmore, 1982 multiaque sequentiæ)
Deixis — Conclusion (frames)

- Mention of one concept evokes or activates the entire containing frame.
  - Whole networks of discourse can be activated and grounded without explicit mention.
  - E.g., the forks from the restaurant.
  - They become salient in the discourse context.

This is surprising — natural language is crazy hard.

- Mention of one concept evokes or activates the entire containing frame.
Implicature — Pt I

- We’ve seen that by relying on
  - Context
  - The addressee’s ability to infer intention

  we can be perceived as meaning **more** than what we actually say

- Can we say more about exactly *how* this works?
A: "Can you tell me the time?"
B: "Well, the milkman has come."

A lot of inferences have to be made to construe B as a cooperative response to A.
Implicature — Pt I (Examples)

- But how do they work?
  - ... and many more
  - "The flag is white.
  - "The flag is white.
  - "The flag is white.
  - "The flat is white.
  - "The flat is white.
  - "and only"
  - "The capital of France is Paris and the capital of England is London.
  - "The capital of France is Paris and the capital of England is London.
  - "The Lone Rang... until the sun set."
Implicature — Pt II

- Gricean maxims of conversation
  - Inhere in the cooperative principle
  - Make your contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.
The maxims may be observed or flouted (exploited)

- The maxim of Manner
- The maxim of Relevance
- The maxim of Quantity
- The maxim of Quality

Gricean maxims of conversation

Implied - Pt II
The maxim of Quality

i. Try to make your contribution one that is true,

ii. Do not say what you believe to be false

iii. Do not say that for which you lack adequate evidence

Specifically:

a. Try to make your contribution one that is true,
Implicature — Pt II

1. The maxim of Quality
   i. Make your contribution as informative as is required for the current purposes of the exchange
   ii. Do not make your contribution more informative than is required

2. The maxim of Quantity
1. The maxim of Quality

2. The maxim of Quantity

3. The maxim of Relevance

Make your contribution relevant
1. The maxim of Quality
2. The maxim of Quantity
3. The maxim of Relevance
4. The maxim of Manner

iv. Be orderly
iii. Be brief
ii. Avoid ambiguity
i. Avoid obscurity

4. Be perspicuous, and specifically:

iii. Avoid ambiguity
ii. Avoid obscurity
i. Avoid obscurity
1. The maxim of Quality
2. The maxim of Quantity
3. The maxim of Relevance
4. The maxim of Manner

This may seem a philosopher’s utopia.
But Grice means we assume and exploit these subconsciously.

This is how we manage inferences from “cooperativeness”.

Implicature – Pt II
Implicature – Pt III

This is not your grandmother’s notion of “linguistic meaning” — this is “please guess what I’m thinking”.

The conversational implicatures are the inferences we make by assuming the maxims of conversation and the cooperative principle.

The conversational implicatures are the inferences we make by assuming the maxims of conversation.
Recall now:

- **Illocutionary force** — inferred communicative intention
  - *e.g.* «request that you pass me the salt»

- **Perlocutionary force** — inferred non-communicative intention
  - *e.g.* «physical effect such that the salt ends up in front of me so that I can use it»

Typically enough to get addressee to infer perlocutionary intent
We got a metaphor to go through by exploiting the maxim of quality.

This question has given rise to an important field in cognitive linguistics: conceptual metaphor theory.

- How often does this sort of thing happen in NL?
- We got a metaphor to go through by exploiting the maxim of quality.
Metaphor — Pt II

More is up; less is down.

The number of books printed each year keeps going up. His draft number is high. My income rose.

He ranks above me in strength. He’s in the high command. She’s in the upper echelon. His power rose.

I have control over her. I am on top of the situation. He’s in a superior position. She’s at the height of her power. He’s in the high command. She’s in the upper echelon. His power rose.

Having control of force is up; being subject to control of force is down.

If you’re too hot, turn the heat down. Temperatures are plunging. I got a low score on the test. Etc.

Errors he made was incredibly low. His income fell last year. He is underaged. If you’re too hot, turn the heat down. Temperatures are plunging. I got a low score on the test. Etc.

The amount of artistic activity has gone down in the past year. The number of errors he made was incredibly low. His income fell last year. He is underaged. If you’re too hot, turn the heat down. Temperatures are plunging. I got a low score on the test. Etc.

The low man on the totem pole. She’s high up on the totem pole. Etc.
Metaphor — Pt II (continued)

...These can combine and interact ... ○ Understanding is Seeing ○ An Argument is a Container ○ An Argument is a Journey ○ An Argument is a Building ○ Can you think of any others? ○

Metaphor — Pt II (continued)
Conceptual metaphor theory would claim that most language is metaphorical in this sense, grounded in embodied experience. The classic theory is due to Lakoff and Johnson.
Metaphor — Conclusions

- Begs the question:
  - How much success will NLP have w/o access to general reasoners?
  - Is a simulation of the embodied condition necessary in order to process artificially the richness of NL?

- Of course, we’re not the first to ask this ...

- Embodied Construction Grammar (Nancy) Chang & (Benjamin) Bergen — ECG
Some initial conclusions
Before we proceed ... (Pt I)

- Sense Knowledge
- Appears to interact in complicated ways with common
- Context-dependent
- Appears to rely on very general reasoning abilities

This stuff is hard

Before we proceed ... (Pt I)
This stuff is important

Before we proceed ... (Pt II)

● "I went to a restaurant last night. The forks were dirty."

● "Are you really going to eat all that?"

● "Do you know where John is?" — "I saw a yellow VW ..."

● "Do you know how?" — "I need to know how.

● "Could you tell me how?" — "I need to know how.

"Could you tell me how to get to the front desk?" — "Could
Before we proceed ... (Conclusion)

We're gonna be looking at sequences of this stuff

● Accumulative context

● Interactions between time indices

Our task is to try and come up with a game-theoretic way of analyzing it.

First we should briefly review some classical theories ...
An introduction to human dialogue
The joint attention management model

Cognitive psychological perspective

Dialogue is joint attention management

"Intending that others jointly attend" (Tomasello, 1998)
How does this help us?

Attentional model – Pt II
Attentional model — Pt II

How does this help us?

All dialogue is:

- Joint (intersubjective)
- Collaborative
- Negotiative (i.e., recursive grounding and repair sequences)
- Inferential (re: attention)

Attentional model — Pt II
The dialogue grammar model

Origins perhaps in 1971 paper by C. L. Hamblin

Mathematical Models of Dialogue

But productive...

Misguided, to put it kindly

Some of this work refers to interactions in dialogue as conversational “games”

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The dialogue grammar model

- Highly domain-dependent
- Brittle
- Based on hand-written rules

... Dialogue systems written using these models tend to be brittle and highly domain-dependent. David Traum (USC) led to the more powerful Information State model.

- Moves amount to our dialogue acts
- Transitions between states are "moves"

In these models, dialogue construed as a path through an RTN
The sequence organization model

Field of Conversational Analysis

○ How language users manage the interaction
  ○ How a linguistic interaction is organized

Study of how meaning unfolds over the course of social interaction

... ethnomethodology of (Harold) Garfinkel and (Erving) Goffman

... Originated in sociology, specifically

Founded by Sachs, Schegloff, Jefferson
The sequence organization model

- Repair
  - Sequence collapse
  - Sequence expansion
- Adjacency pairs (first pair part, second pair part)
  - Next speaker selection
  - TRP, or Transition Relevance Place
  - TCU, or Turn-construction unit (= utterance, roughly speaking)
- Turn-taking behavior

The sequence organization model
The contribution model

- Once again, we have cooperation
- Presented and accepted -> grounded
- Joint action

Contribution (to common ground)

- Joint action
- Present and accepted

Contribution (to common ground)

- Language, pragmatics, and CA

They also synthesize much early work in the philosophy of

Due to (Herbert) Clark and (Edward) Schaeffer

Cognitive Linguistics and Cognitive Psychology

The contribution model
(To the rescue...?)

Game Theory
Recap: natural language is hard

Many natural tasks in NLP require very little “real” understanding of language:

- Word-sense disambiguation,
- Question answering,
- Document classification, *and even*
- Document summarization
Recap: natural language is hard

But the buck stops with dialogue –

So when you let people talk to a computer the way they really talk –

We assume a lot of "pre-loaded" common ground

- Knowledge of social/linguistic conventions
- Common-sense knowledge

And when we say "cooperativeness" in a technical, linguistic sense –

- We assume "pre-loaded" common ground

Recap: natural language is hard
It's possible game theory can help...

- Recent (i.e., few years) resurgence in dialogue systems research via...
- Many encouraging initial results (Serban, Courville, Bengio, Pineau...)
- Lack of productive research on applying game theory to dialogue systems research was abandoned for a decade but we still need to figure out how...

Neural dialogue systems...
Beginning with neural dialogue systems...

- ... or how to integrate common sense knowledge
- Contributitional nature of dialogue
- It is still unclear how to model the cooperative
- NDS are not an automatic panacea
  - But it is clear:
  - Can model hierarchically time dependencies (context)
  - ANNs are with some mild assumptions, general function
  - Approximators

Nirat and I have attacked the problem from this angle...

... with neural dialogue systems...
Thoughts...

- I do have some thoughts...
- Before I proceed...
- ... do you have any thoughts about what game theory might have to say about NL dialogue?
Cooperative game

- actions \rightarrow \text{dialogue (speech) acts}
- players \rightarrow \text{dialogue participants}

First approximation

Thoughts...
Thoughts...

- First (high-level) approximation
  ○ players -> dialogue participants
  ○ actions -> dialogue (speech) acts
  ○ players -> dialogue participants

- Cooperative sequential imperfect information game
  ▪ Strategies unfold over turns
  ▪ We know $U$, the utterance chosen
  ▪ We are uncertain of $A$, the dialogue act chosen
Thoughts … (cont’d)

Choose the most relevant \( A_n \) in expectation given the information set

We thereby update the information set chosen some \( A_{n-1} \) to maximize relevance\( (A_{n-1}) \) to the current likely dialogue state.

By analogy to the principle of cooperation, Player 2 knows Player 1 has

utility function \( - \text{relevance}(A_n | A_n) \) (relevance of contribution to the current likely dialogue state)

extra-linguistic goals of other players(s)?

likely sequence of \( A_n \) in

information set \( \rightarrow \text{distribution over} \)

…”
Thoughts (cont’d)

Enormous room for refinements...

- Real-time NL data is noisy and mistake-prone
- Learn from data via ML?
- Difficult to measure relevance?
- Real-time game? Differential game?
- Substrate via monitoring, feedback, inference
- In NL dialogue, turn-taking organization arises out of a real-time turn-based

- Enormous room for refinements...
Thoughts ... (cont'd)

- Not yet formal enough for implementation
  - May also still profitably influence or guide the design of an algorithm, architecture, or procedure...
Some conclusions

For the sleepy
What we learned...

Words

- NL is hard
  - NL use is fundamentally cooperative
  - Meaning is inferred from common ground (context + shared assumptions + common sense), not given by words.

What we learned...
What we learned … (cont’d)

- Dialogue is harder
  - Common ground (CG) accumulative
  - Contributions
  - Update CG

must be mutually accepted and known to be accepted
What we learned ... (cont'd)

- Game theory may be able to help by providing a framework for modeling dialogue as a cooperative, dynamic game.
- Shared public objectives of relevance, coherence, cooperativity.
- Potentially disjoint private objectives of individual linguistic goals (express an opinion) and individual extra-linguistic goals (schedule an appointment).

...