Language and Equilibrium

An Introduction to Prashant Parikh's Theory of Equilibrium Semantics

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Development through the years.

- The Use of Language (2001)
- Language and Equilibrium (2010)
- Communication and Content (2019)

Main Reference: langsci-press.org/catalog/book/248
Parikh, Prashant. 2019. Communication and content. (Topics at the Grammar-Discourse Interface 4). Berlin: Language Science Press. DOI: 10.5281/zenodo.3243924

This talk: Equilibrium Semantics

1. Meaning as constituted by Communication
2. Quick Introduction to Game Theory
3. Overview of Situation Theory
4. Formulating Communication Games
5. Strengths and Weaknesses

1. Meaning as constituted by Communication

Communication is central to meaning

- What goes wrong when directly associating words to *real* objects in the world?
- Gottlob Frege (1848–1925), sometimes called the father of modern semantics, held the belief that meaning comes from the interaction of language and truth. He gave this puzzle.
  - "Hesperus is Phosphorus" [1]
  - "Hesperus is Hesperus" [2]
- They both refer to the planet Venus (as the *Morning Star* and *Evening Star*)
- Since they refer to the same object (*truth*), they are equivalent.
- Reconciled by differentiating *sense* from the *reference*.
- An intermediary idea of "sense" which isn't quite *truth* was required. This was Problematic.

Communication is central to meaning

- Frege did not sufficiently articulate the distinction between a sentence and an utterance.
- Many problems arise when characterizing Meaning with respect to truth.
- Rather, Meaning emerges from the interactions of Agents in shared situations. It's definition must rely more on the subjective experience of agents, than some universal notion of truth.
- It was the later Wittgenstein, followed by Austin, and Grice and other *ordinary language philosophers* who realized the importance of seeing language as a situated activity but did not quite succeed in unraveling this elusive concept. [p.6]

Theories of communication

Table 1.1: Summary of theories of communication

	Logicism	Wittgenstein	Austin	Grice	Lewis	Eq. Sem.
context	marginal	implicit	implicit	implicit	implicit	Yes
action	partial	yes	yes	yes	yes	Yes
epistemic interaction	no	no	implicit	yes	yes	Yes
practical interaction	no	implicit	no	no	partial	Yes
social interaction	no	no	no	no	no	Partial
computable	no	no	no	partial	partial	Yes

2. Quick Introduction to Game Theory

What is a game?

- $\langle I, \mathbf{S}, \mathbf{U} \rangle$
- Agents
- Actions
- Payoffs (Utility)

	Grand Central	Penn Station
Grand Central	(2,2)	(0,0)
Penn Station	(0,0)	(1,1)

Figure 2.1: A coordination game G in normal form

- Agents are *Rational* and *Intelligent*
- Facts of the Game are *Common Knowledge*
- *Nash's Theorem:* Every finite strategic form game has an equilibrium.

Extensive Form Game

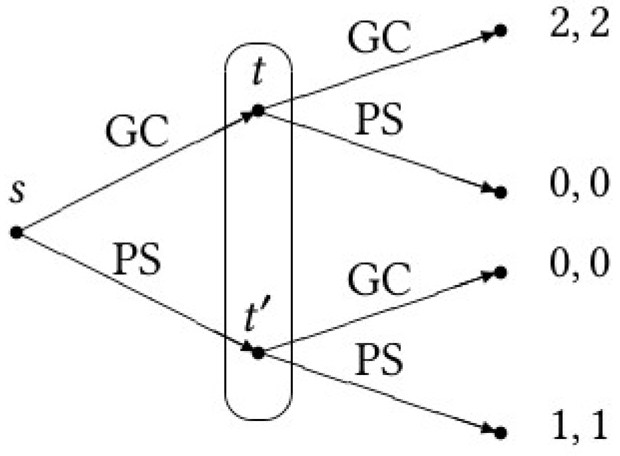

Figure 2.2: Extensive form for G

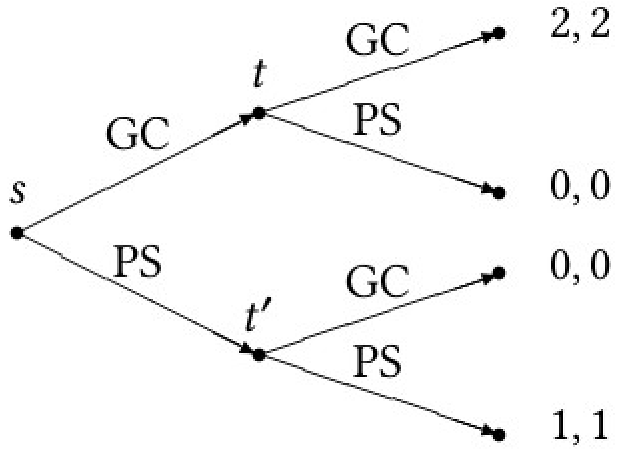

Figure 2.3: Extensive form for G'

3. Overview of Situation Theory

A Hierarchical Model

- Reality: The whole of it
- Ontologies (*Information*): Reality as viewed by agents
- Environments: where *Real* Games happen
- Situations: where Communication Games happen
- Infons: smallest facts

Situation Theory

- Jon Barwise & John Perry. 1983. Situations and attitudes. Cambridge, MA: The MIT Press.
- The relation between a situation s and an infon σ that holds in it is written $s \vDash \sigma$ or $\sigma \in s$, and is described by saying s supports σ or σ holds in s.

How are infons represented?

- Consider an utterance of "bill smith ran" [p.16]
- Basic infons are $(n + 4)$-tuples $\langle\langle\, R; a1 \,;\, \ldots \,;\, an \,;\, l; t; 1 \,\rangle\rangle$ made up of individuals standing in relations a certain locations l and times t with the last item, the number 1, being its polarity, indicating the relation holds.
- Bill Smith ran can be expressed partially as ⟨⟨ ran; Bill Smith ⟩⟩ or more formally as $\langle\langle\, R$ ran ; $b \,\rangle\rangle$ where R ran is a relation.
- Partial infons such as $\langle\langle\, R; a1 \,;\, a3 \,\rangle\rangle$ or even $\langle\langle\, a1 \,\rangle\rangle$ are legitimate infons.
- A partial order $\Rightarrow\ell$ on I that captures the relation "is at least as informative as" or "is at least as strong as" is assumed.

  Eg. $\langle\langle\, P$ crimson ; $a \,\rangle\rangle \Rightarrow\ell \langle\langle\, P$ red ; $a \,\rangle\rangle$,

  $\langle\langle\, P$ spinster ; $a \,\rangle\rangle \Rightarrow\ell \langle\langle\, P$ female ; $a \,\rangle\rangle$

A whole set of Algebraic properties!

Reflexivity: $\sigma \Rightarrow_\ell \sigma$

Antisymmetry: If $\sigma \Rightarrow_\ell \tau$ and $\tau \Rightarrow_\ell \sigma$ then $\sigma = \tau$

Transitivity: If $\sigma \Rightarrow_\ell \tau$ and $\tau \Rightarrow_\ell \upsilon$ then $\sigma \Rightarrow_\ell \upsilon$

- Let $\vee$ and $\wedge$ be the induced join and meet operations. If $\tau = \sup\{\sigma, \sigma'\}$, then $\tau = \sigma \vee \sigma'$, and if $\tau = \inf\{\sigma, \sigma'\}$, then $\tau = \sigma \wedge \sigma'$.
- A lattice is complete if all of its subsets, finite or infinite, have both a join and a meet. There is no reason to restrict $\vee$ and $\wedge$ to finite subsets so we assume $(I, \Rightarrow_\ell)$ is complete.
- Metric: A valuation on I is a real-valued function $v : I \to \mathbb{R}$ such that $v(\sigma) + v(\tau) = v(\sigma \vee \tau) + v(\sigma \wedge \tau)$. A positive valuation is one where $\sigma \Rightarrow_\ell \tau$ implies $v(\sigma) < v(\tau)$.
- A metric lattice is a lattice with a positive valuation and the corresponding metric is given by:

$$\delta(\sigma, \tau) = v(\sigma \vee \tau) - v(\sigma \wedge \tau)$$

Language and Syntax

- Three algebraic systems:

$$(\mathrm{I}, \odot_u), (\mathrm{L}, \bigcirc_G), (\mathrm{T}, \star_{G,u})$$

- Semantics, Language,

  and Syntax

4. Formulating Communication Games

Definition 5.3. $\mathcal{A}$ communicates p to $\mathcal{B}$ by uttering φ in u if and only if $\mathcal{A}$ intends (possibly partly implicitly) to convey p to $\mathcal{B}$ in u, $\mathcal{B}$ intends (possibly partly implicitly) to interpret $\mathcal{A}$'s utterance of φ in u, and the games $G_u^{\mathcal{A}}(\varphi)$, $G_u^{\mathcal{B}}(\varphi)$, $G_u(\varphi)$ induced thereby are equal and common knowledge and their solution is p.

p.69

An *Utterance Situation* in a Communication Game

- Setting Game
    - A's wish to elicit some response from B
  - Content Selection Game
    - A's equilibrium content
  - Generation Game
    - A's equilibrium utterance
  - Interpretation Game
    - B's equilibrium content
  - Content Selection Game
    - B's equilibrium response
- Back to the Setting Game

	Restaurant one	Restaurant two
Restaurant one	(3,2)	(0,0)
Restaurant two	(0,0)	(2,3)

5. Strengths and Weaknesses

Strengths and Weaknesses

- Generalizable.
- Avoids the pesky notion of *truth.*
- Meaning as a natural phenomenon.
- Claims to capture Illocutionary meaning.
- Infons serve as a concrete representations for implementation.
- Hard coding of semantic relationships is unnecessary.

- Unsystematic as opposed to bottom up theories. [Feature not a bug. This for Wittgenstein was a merit and he stressed the diversity of linguistic acts.]
- Computationally expensive. [Break down the model into many small games as opposed to few large games.]
- Very little implementations. No yardstick to measure against.