

Lecture 7

Information Structure *ala* Steedman

Steedman's IS Partitioning

(Steedman, 2000b; Steedman, 2000a) distinguishes two dimensions of IS within a sentence:

Theme-Rheme partitioning reflects an *aboutness* relation, i.e., the Rheme is semantically predicated over the Theme. This dimension connects the utterance to the rest of the discourse.

Background-Focus partitioning within Theme and Rheme reflects an abstract notion of “kontrast” between alternatives available in the discourse context, against which the Theme and Rheme of the actual utterance are cast. Words whose interpretation contributes to distinguishing Theme/Rheme from alternatives belong to Focus, other words belong to Background.

Outline

- Steedman's two dimensions of IS
- Alternative sets semantics of IS
- IS and intonation
- IS and various aspects of multimodal interaction

Steedman's IS Partitioning

- (152) What do you know about Marcel? Marcel proved COMPLETENESS
H* LL%
Theme Rheme Focus
- (153) I know which result Marcel predicted. But which result did Marcel prove?
 Marcel PROVED COMPLETENESS
L+H* LH% H* LL%
Focus Focus
Theme Rheme
- (154) I know who proved soundness. But who proved completeness?
 MARCEL proved COMPLETENESS
H* L L+H* LH%
Focus Focus
Rheme Theme

The Semantics of IS

- Semantics of IS in terms of selecting one member from a *presupposed set of alternatives* (Steedman, 2000a), following (Rooth, 1992; Büring, 1997)
 - Theme presupposes a *Rheme-alternative set*, i.e., a set of alternative propositions that could possibly answer the corresponding question in the given context; Rheme then restricts the Rheme-alternative set to a singleton
 - Theme also presupposes a *Theme-alternative set*, i.e. a set of alternative questions; Focus within Theme then restricts the Theme-alternative set to a singleton
- These are pragmatic presuppositions that the relevant alternative set(s) be available in the context. They can get bound or accommodated.
- The systematic recognition of the alternative sets, and their maintenance as a discourse progresses are open research issues.

Kontrast

(Vallduví and Vilkuna, 1998) propose to use *kontrast* as a cover term for several operator-like interpretations of “focus” in the literature: identificational foci, exhaustiveness foci, contrastive foci and contrastive topics, and also interrogative wh-words

If an expression *a* is kontrastive, a *membership set* $M = \{\dots, a, \dots\}$ is generated and becomes available to semantic computation as some sort of quantificational domain. (A set of alternatives for the kontrasted constituent is generated as an additional denotation, cf. (Rooth, 1985b; Rooth, 1992).)

(155) John introduced BILL to Sue.

$$M = \{Bill, Carl, Mark\}$$

The membership of *M* is determined ontologically and contextually.

The Semantics of IS

(185) Marcel PROVED COMPLETENESS.
 L+H* LH% H* LL%
 Background Focus Focus
 Theme Rheme

(156) *prove' completeness' marcel'*

(157) $\exists x. \star \textit{prove}' x \textit{marcel}'$

(158) $\{ \textit{prove}' \textit{completeness}' \textit{marcel}' , \textit{prove}' \textit{decidability}' \textit{marcel}' , \textit{prove}' \textit{soundness}' \textit{marcel}' \}$

(159) $\{ \exists x. \textit{prove}' x \textit{marcel}' , \exists x. \textit{predict}' x \textit{marcel}' \}$

The Semantics of IS

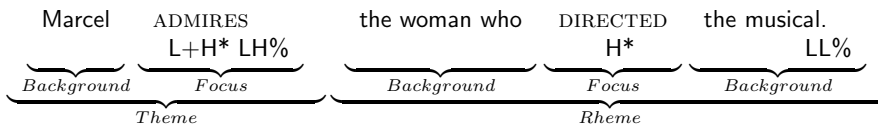
(160) I know that Marcel likes the man who wrote the musical.
 But who does he ADMIRE?

Marcel ADMIRES the woman who DIRECTED the musical.
 L+H* LH% H* LL%
 Background Focus Background Focus Background
 Theme Rheme

- the Background/Focus partitioning of this Rheme is supported just in case all individuals considered have something to do with the musical, and the property of directing it uniquely identifies one such individual (Prevost and Steedman, 1994; Prevost, 1995; Steedman, 2000b)



The Semantics of IS



(161) *admire' woman₁' marcel'*

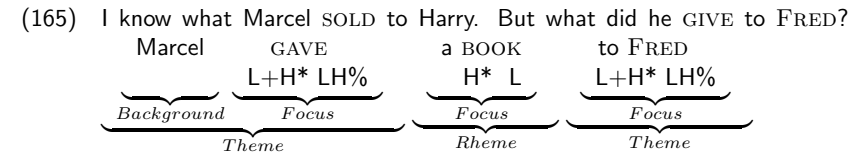
(162) $\exists x. \star \textit{admire}' x \textit{marcel}'$

(163) { *admire'woman₁'marcel'*, *admire'woman₂'marcel'*,
admire'man₁'marcel' }

(164) { $\exists x. \textit{admires}' x \textit{marcel}'$, $\exists x. \textit{likes}' x \textit{marcel}'$ }



The Semantics of IS



(166) *give' fred' book' marcel'*

(167) $\exists x. \star \textit{give}' \star \textit{fred}' x \textit{marcel}'$

(168) { *give' fred' book' marcel'*, *give' fred' record' marcel'*,
give' fred' biscuit' marcel' }

(169) { $\exists x. \textit{give}' \textit{fred}' x \textit{marcel}'$, $\exists x. \textit{sell}' \textit{fred}' x \textit{marcel}'$,
 $\exists x. \textit{give}' \textit{harry}' x \textit{marcel}'$, $\exists x. \textit{sell}' \textit{harry}' x \textit{marcel}'$ }



IS and Intonation

(Steedman, 2000b; Steedman, 2000a) proposes a compositional account of the semantics of tones for English, cast in CCG

- Theme/Rheme partitioning determines overall intonation pattern
 - Theme and Rheme as one intonation phrase each (boundary between)
 - Theme-accents: L+H*, L*+H (prototypical Theme-tune: L+H*LH%)
 - Rheme-accents: H*, L*, H*+L, H+L* (prototypical Rheme-tune: H*LL%)
- Theme and Rheme as one intonation phrase each (boundary between)
- Background/Focus partitioning Determines placement of pitch accents
 - Focus: (words) marked by pitch accent
 - Background: (words) without pitch accent



IS and Intonation

- (170) Q. Does Marcel like opera?
- a. *A: Marcel likes* MUSICALS.
H* LL%
 - b. *A: Marcel likes* MUSICALS.
L+H* LL%

(170b) is *all-theme*: speaker offers a new theme, and hence a new rheme alternative set; not taking responsibility for a rheme indicates lack of commitment to whether the utterance answers the question (lack of confidence and/or certainty that a particular inference can be drawn)



IS and Intonation

H% boundary marks themes and rhemes alike as *hearer's* responsibility.

(171) Polite declarative rhemes:

a. *There's ORANGE juice, and APPLE juice.*

H* LH% H* LL%

b. *Your LUNCH is ready!*

H* LH%

(172) Q. I know that the result of the exercise was to prove completeness.
But what was the whole point of the exercise?

A. *THAT was the whole POINT of the exercise!*

H* L+H* LH%



IS-Based Intonation Assignment in Practical Systems



IS and Intonation

L* seems to mark rhemes like H* does, but additionally involve an associated speech act of denial (similarly to the Latin particle *num*):

(173) *Do PRUNES have FEET?*

L* L* LH%

(the questioner presumes the answer to be negative)

(174) *Do PRUNES have FEET?*

H* H* LH%

H*vs. L* distinction can also be used indirectly in polite offers of alternatives:

(175) *There's ORANGE juice, and APPLE juice.*

L* LH% H* LL%

(increased diffidence in comparison with (171a))



IS-Based Intonation Assignment

- question-answer pairs: En. (Prevost, 1995),
- dialogue system output: Ger., En. (Kruijff-Korbayová et al., 2003); En. (Moore et al., 2004; Baker et al., 2004)
- continuous "speech": En. content-to-speech generation (Prevost, 1996); En. text-to-speech generation (Hiyakumoto et al., 1997)
- non-linguistic aspects in modeling embodied conversational agents: gestures (Pelachaud et al., 1998; Cassell et al., 2000), gaze and turn-taking (Cassell et al., 1999)



Intonation in Answers to Question



Intonation in Answers to Questions

- Using IS to control intonation of synthesized spoken output in answers to questions: question IS fully determines the answer IS (Prevost and Steedman, 1993)
- Theme/Rheme determination:
 - rheme of the question determines the theme of the answer
- Focus determination:
 - terms focused in question are focused in answer
 - term instantiating question variable is also focused
 - for more complex rhemes, only *new* elements are focused



Prevost: Example

- (176) *I know that widgets contain cogs,
but what parts do WODGETS include?*
 L+H* LH% H* LL%
- prop: $s : \lambda x[\text{part}(x) \& \text{include}(\star \text{wodgets}, x)]$
 theme: $s : \lambda x[\text{part}(x) \& \text{include}(\star \text{wodgets}, x)] /$
 $(s : \text{include}(\star \text{wodgets}, x) / \text{np} : x)$
 rheme: $s : \text{include}(\star \text{wodgets}, x) / \text{np} : x$
- (177)
 prop: $s : \text{include}(\star \text{wodgets}, \star \text{sprockets})$
 theme: $s : \text{include}(\star \text{wodgets}, x) / \text{np} : x$
 rheme: $\text{np} : \star \text{sprockets}$
- WODGETS *include* SPROCKETS.
 L+H* LH% H* LL%



Intonation in Answers to Questions

- (Prevost and Steedman, 1994): IS determination in answer not from question alone but also from discourse model (database)
- Theme/Rheme determination:
 - rheme of the question determines the theme of the answer
- Focus determination:
 - terms focused in question's rheme are focused in answer's theme
 - rheme-focus in answer determined from alternative sets in the database



Constructing Rheme-Alternative Sets

(Prevost and Steedman, 1994):

Given database D , object x and a set of properties P that uniquely describe x :

1. construct a set of objects, A , (and their referring properties) which can be considered alternatives to x w.r.t. D
2. restrict A by properties of objects mentioned in theme $\rightarrow A'$
3. mark as contrastive those properties of x in P that exclude some alternatives from A'



Intonation in Dialogue System Output



IS in Answers to Questions: Summary

- IS and WO (Hoffman); IS and intonation (Prevost); formalization in CCG
- Theme/Rheme determined by IS in question (differences in IS assignment in questions between Hoffman and Prevost!)
- Focus is determined from (a) question, (b) contrast w.r.t. alternatives in discourse model (database)
- Hoffman's database contains propositions and is organized by themes (entities)
- Prevost's discourse model (database) contains entities, propositions, and themes and rhemes



Intonation of Spoken Dialog System Output

SIRIDUS project: (Kruijff-Korbayová et al., 2003)

- Most current systems have limited dialogue flexibility, which enables them to use carefully scripted interactions with predefined and prerecorded output
- However, flexible interaction requires output to be dynamically generated
- The realization of dynamically generated output needs to be controlled, to ensure that it is contextually appropriate
- In particular, the intonation of synthesized spoken output needs to be controlled w.r.t. the context

SIRIDUS Example

U: Which devices are in the house?

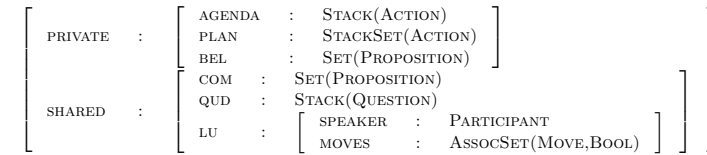
S: There is a *STOVE* in the *KITCHEN*, a *RADIO* in the kitchen
 H* H* LH% H* LH%
 and a radio in the *BATHROOM*.
 H* LL%

U: What is the status of the devices in the kitchen?

S: The *STOVE* in the kitchen is ON.
 L+H* L% H*LL%
 The *RADIO* in the kitchen is OFF.
 L+H* L% H*LL%

Information-State Update Approach to Dialogue Modeling

- Dialog moves are modeled as information state update transitions
- Information State represents the current discourse context (in a dialogue participant's view)
- e.g. a version of the Dialogue Game Board (Ginzburg, 1996) in GoDIS:



Information Structure Assignment

Theme/Rheme partitioning: determined according to the QUD

- **QudTR** rule: given an utterance content u to partition, if QUD corresponds to the result of λ -abstracting over a part of u , this part is marked as the Rheme

If on QUD: $?\lambda x. \text{status}(x)$,
 then $\text{status}(\underbrace{\text{on}}_{\text{Rheme}})$

Information Structure Assignment

Background/Focus partitioning: determined by comparing parallel elements

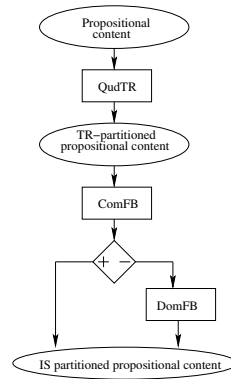
- **ComFB** rule: if there is an element in the **shared commitments** that is parallel but not identical to an element in the utterance content, the part that is non-identical is marked as the Focus, e.g.:
 If in shared commitments: $\{ \text{type}(\text{stove}) \& \text{location}(\text{kitchen}); \text{type}(\text{radio}) \& \text{location}(\text{kitchen}); \text{type}(\text{radio}) \& \text{location}(\text{bathroom}) \}$
 then $\text{type}(\text{ stove }) \& \text{location}(\text{kitchen})$

$\underbrace{\hspace{10em}}_{\text{Focus}}$

- **DomFB** rule: if there is an element in the **domain model** that is parallel but not identical to an element in the utterance content, the part that is non-identical is marked as the Focus

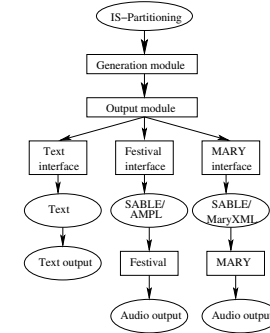


Information Structure Assignment



Experimental Implementation

Producing synthesized output with contextually varied intonation in GoDiS



SIRIDUS: Summary

- Domain- and application-independent rules determining IS partitioning from the information state
- Domain- and application-independent rules mapping IS partitioning to realization through intonation (in template-based generation)
- Experimental implementation using TTS systems which support ToBI-based intonation determination
- Test-of-concept evaluation with good results



FLIGHTS

- Fancy Linguistically Informed Generation of Highly Tailored Speech (Moore et al., 2004; Baker et al., 2004)
 - tailored descriptions of the most relevant available options and their attributes in information-seeking dialogue (flight information)
 - content selection and contextually appropriate information presentation in order to make descriptions easy to understand and memorable:
 - * taking user preferences into account when deciding about various aspects: referring expressions, aggregation, discourse cues, scalar terms
 - * contextually appropriate intonation
- Approach to IS based on (Steedman, 2000a)



Example: Tailored Descriptions

- (178) There's a direct flight on BMI with a good price – it arrives at four ten p.m. and costs a hundred and twelve pounds. The cheapest flight is on Ryanair – it arrives at twelve forty-five p.m. and costs just fifty pounds, but it requires a connection in Dublin. (student)
- (179) You can fly business class on British Airways, arriving at four twenty p.m., but you'd need to connect in Manchester. There is a direct flight on BMI, arriving at four ten p.m., but it has no availability in business class. (business traveller)



Example: APML Coding of IS and Intonation

```
(180) <apml>
  <performative type='inform'>
    <rheme>
      The <emphasis x-pitchaccent='Hstar'>KLM</emphasis>
      Airlines flight <boundary type='L'>/>
    </rheme>
    <theme>
      leaves <emphasis x-pitchaccent='LplusHstar'>
      Edinburgh<.emphasis> at
      <emphasis x-pitchaccent='LplusHstar'>eleven a.m.</emphasis>
    <boundary type='LH'>/>
    </theme>
  </performative>
</apml>
```



FLIGHTS: IS Determination

- content planner determines theme/rheme and focus/background
- OpenCCG realizer makes intonation choices
- Intonation markup for TTS using APML, an XML markup for specifying turn-taking, performative, affective and informational aspects of text
- TTS with Festival cluster unit synthesis, using restrictions on unit types which reflect pitch accents and boundary tones, cf. ToBI (Silverman et al., 1992)
- Evaluation by perceptual comparison between different versions, on descriptive sentences and clarification requests (significant results)



Summary: IS in Dialogue System Output

- to my knowledge, only intonation until now
- IS assignment using utterance content (e.g., contrast) and context (e.g., previous theme(s), question under discussion)
- IS → intonation mapping
- speech synthesizers capable of handling high-level intonation specifications, e.g., ToBI in Festival and Mary (Schröder and Trouvain, 2001)
- perceptual evaluation results positive



Intonation in Continuous “Speech”



IS-Based Assignment of Intonation in Text

- Previous work: accenting affected by “givenness” (Hirschberg 1990), (Hirschberg, 1993)
- (Prevost, 1996):
 - accenting based on (a) old/new; (b) contrast
 - text organization takes thematic progression into account (prefers theme continuation)



IS-Based Assignment of Intonation in Text

- Content and text planning: determine a sequence of propositions about an object and the rhetorical relations, segment each proposition into theme/rheme
 - discourse model contains previous themes and rhemes (ISstore)
 - to determine theme, search for most recent match, prefer theme-continuation
 - determine rheme as complement of theme
- Sentence planning: determination of realization, focus assignment
 - each new (not mentioned) property or discourse entity get focus
 - contrasting elements get focus



Assigning Contrastive Focus

Step 1: Determine contrasting propositions

- containing 2 contrasting pairs of entities or 1 pair of contrasting entities and contrasting functors
- discourse entities are contrasting when they are alternatives w.r.t. isa in DB

Step 2: Contrastive focus algorithm

Given: object x , properties P , alternatives A :

1. restrict A to objects mentioned in discourse $\rightarrow A'$
2. for each property p in P , include p in set of contrasting properties P_c iff p excludes some object from A'



IS-Based Intonation in Text-To-Speech

- Previous work: accenting affected by “givenness” (Hirschberg 1990), (Hirschberg, 1993)
- (Hiyakumoto et al. 1997):
 - combine first mention and contrastiveness as reasons for accenting
 - use of WordNet in givenness and contrast determination: to identify sets of synonyms and contrasting words for open-class words (nouns, verbs, adjectives, adverbs)
 - determine theme/rheme in propositional constituents by heuristics applied to pre- and post-verbal and verb-complex material, and considering presence of focus within it



Summary: IS in MT, Text Generation and TTS

- IS and WO; IS and intonation
- Theme/Rheme determined by (a) linking in text (centering; theme continuation); (b) genre-specific thematic scaffolding; (c) heuristics
- Focus is determined by (a) discourse newness, (b) contrast w.r.t. alternatives in discourse model
- Combination of contextual and grammatical factors (CCG, SFG)



IS in Multimodal ECA Interaction

- Appropriate and synchronized speech, intonation, facial expressions and hand gestures (Pelachaud et al., 1998)
- Integrating turn-taking and IS provides better explanation for gaze behavior (Cassell et al., 1999)
- Generation of either speech, gesture or combination of both as a function of IS status and surprise value of a discourse entity (Cassell et al., 2000)
- Various researches have observed that distance, posture shifts and other body movements seem to accompany changes in the topic or social relationship



IS in Multimodal Interaction



IS and Gestures

Gilbert and George (Pelachaud et al., 1998);

Greta ECA (<http://www.iut.univ-paris8.fr/greta/>)

- Some facial expressions are automatically generated according to intonation (e.g., raising eyebrows with accented material), based on corpus studies
- Head nods and look-toward listener punctuate accented and emphasized items
- Iconic and metaphoric gestures (i.e., representing something) are generated for
 - rhematic verbal elements (roughly, information not yet spoken about)
 - hearer new references provided that the semantic content can receive such a gesture (e.g., spatial)
- Beat gestures are generated
 - otherwise
 - to accompany discourse new definite references
- Duration of intonation phrases is used to time gestures



Summary

- Steedman's two-dimensional IS partitioning: Theme/Rheme and Focus/Background within each
- semantics: presupposed on alternative sets
- tight correlation with intonation: accent and boundary placement, tune type
- compositional semantics of tones
- successfully applied in a range of practical systems