A Formal Analysis of Iconic Gesture

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Outline

Iconic Gesture: An Example

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So that these very low-level phonological errors tend not to get reported. . .

. . . because they are being produced continually by an iterative process below our level of awareness.

Iconic Gesture: An Example

Now one thing you could do is totally audiotape hours and hours. . .

. . . so that you get a large amount of data that you can think of as laid out on a time line.

Iconic Gesture: An Example

And exhaustively go through and make sure that you really pick up all the speech errors

. . . by individually analysing each unit of analysis along the timeline of your data.

Iconic Gesture: An Example

Allow two different coders to go through it. . .

. . . and moreover get them to work independently and reconcile their activities.

Iconic Gesture: An Example

speech because gesture
speech so that gesture
speech by gesture
speech and moreover gesture

Speech resolves gesture meaning

(1) So that these very low-level phonological errors tend not to get reported

(2) The mouse ran on the wheel

Gesture resolves linguistic meaning

Describing cotter pins in a lock being held in position: (Engle, 2000)

(3) They have SPRINGS.

Right pinched hand (as if holding a small vertical object) is just above left pinched hand (as if holding small vertical object).

- Speech only: collective vs. distributive.
- Gesture depicts a single pin and single spring:
  - ambiguous as to which hand depicts which.
  - Interpretation stems from its iconicity and an inference that it elaborates the speech.
- This resolves speech to a distributive interpretation.

Discourse Coherence

- The current contribution to a discourse is related to a prior contribution by:
  - elaborating it, explaining it,
    drawing a contrast, continuing a narrative etc.
- Relations' semantics go beyond compositional semantics, resolving ambiguities, anaphora etc.
  John said that Bill kissed Mary. Peter did too/But Peter did.
- The relations structure the context, identifying what's salient. New contributions must connect to salient bits.

Advantages in gesture analysis

- Uniform pragmatic theory for communicative actions, in whatever medium.
- Supports gestures contributing distinctive content:
  - speech because gesture Explanation
- Predicts multimodal anomalies:
  - You walk out the doors.
  - Linguistic analogy: You walk out the doors. Turn right. ???Push the door handle down.

Gesture interacts with prosody

Ill formed!

(4) * Your MOTHER called

Syncopation and boogie woogie in music,
but not communication!

Gesture interacts with linguistic syntax

From (Kendon 2004, p.129):

(5) First of all they made everything GREASY in the whole room place.

- Exhaustiveness of greasy stuff. . .
- . . . even if gesture temporally synchronous with made
- But not if gesture temporally overlaps only First or they.

Multimodal Grammar

- Construction rules attach gesture to a phrase:
  - Syntax: Constraints on time, prosody and syntax.
  - Semantics: Introduce an underspecified coherence relation between the content of the speech daughter and the gesture daughter.
- So timing, syntax and prosody constrain what bits of speech content a gesture can be semantically related to.
- Typically have attachment ambiguity, but some readings ruled out by form.

Formalisation

Form-meaning mapping: Use Ivan's Work!

RMRS: to capture the meaning of gesture that's revealed just by the form of the hand movement(s).

HPSG: to articulate how multimodal form constrains meaning.

Context and Interpretation:

Discourse Coherence: helps resolve underspecified content revealed by form to a specific interpretation in context.

Dynamic Semantics: constrains co-reference between speech and gesture and across gestures.
Won't talk about that here.

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Re-using linguistic formalisms yields uniform approach to interpreting communicative acts, whatever their modality.

Gesture Form

(Kopp *et al*, 2004)

- Gesture's form has components:
  - Hand shape, finger direction, palm direction, position (relative to torso), path of movement...

  and each of these potentially reveals stuff about meaning.

Gesture for (1):

$$\begin{bmatrix} \textit{rh-depict} & \\ \text{HAND-SHAPE} & \text{asl-s} \\ \text{FINGER-DIRECTION} & \text{down} \\ \text{PALM-DIRECTION} & \text{left} \\ \text{TRAJECTORY} & \text{sagittal-circle} \\ \text{MOVEMENT-DIRECTION} & \{\text{iterative, clockwise}\} \\ \text{LOCATION} & \text{central-right} \end{bmatrix}$$

Underspecifying Linguistic Meaning: MRS

- Semantic ambiguity without syntactic ambiguity:
  - semantic scope, word senses...
- Underspecified LF is a partial description of logical form.

(6) a. Every french bank has some money.

b. $every(x, french(x) \wedge bank_{s1}(x),$
$\quad some(y, money(y), have_{s2}(e, x, y))$
$some(y, money(y),$
$\quad every(x, french(x) \wedge bank_{s2}(x), have_{s1}(e, x, y))$
...

c. $l_1 : every(x, h_2, h_3),\ l_4 : french(x),\ l_4 : bank(x)$
$l_5 : some(y, h_6, h_7),\ l_8 : money(y),$
$l_9 : have(e, x, y)$
$h_2 \geq l_4,\ h_6 \geq l_8$

Underspecifying Iconic Meaning: RMRS

Factorisation of Elementary Predications

$l_9 : have(e, x, y)$ becomes
$l_9 : a : have(e), ARG1(a, x), ARG2(a, y)$

RMRS can underspecify more stuff:

- what arity predicates have (cf. subcat info) missing ARGs
- what sort and value of arguments they take i
- the argument position of a variable $ARGn(a, x)$
- dependencies missing variable equalities

All needed for mapping gesture form to content.

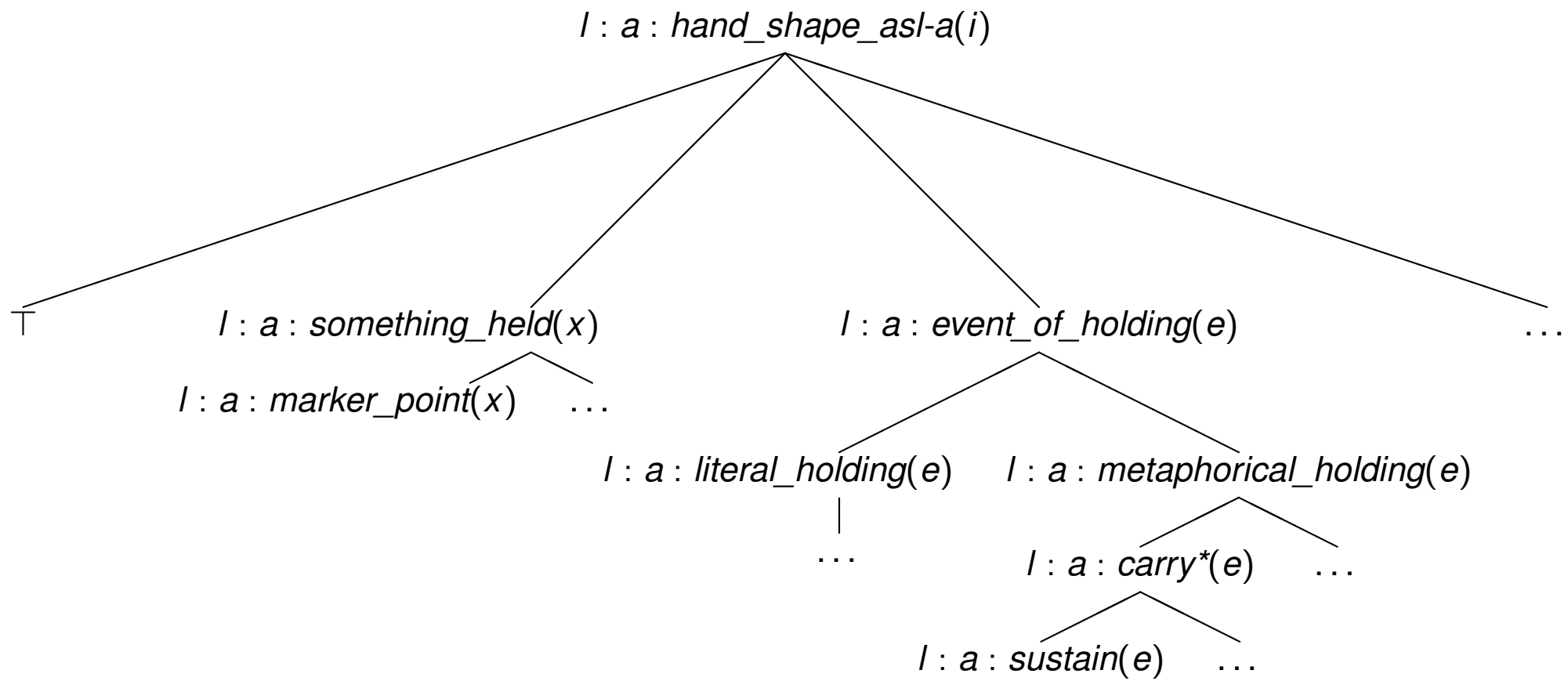
Underspecified semantics of gesture

- Each element in gestural form conveys an analogous bit of descriptive content.
- Convention yields the underspecified predicates from the feature structure:

$$l_1 : a_1 : \textit{hand\_shape\_asl-s}(i_1)$$

- No ARGs or variable equalities

Hierarchy for Resolving Underspecified Predicates



marker_point: 1-place predicate

sustain: 3-place predicate

Example construction rule (simplified)

Situated Spoken Phrase Constraint

A gesture can attach to a temporally overlapping constituent and any of its higher projections.

They made everything GREASY in the whole room.

- greasy ⇑ whole clause

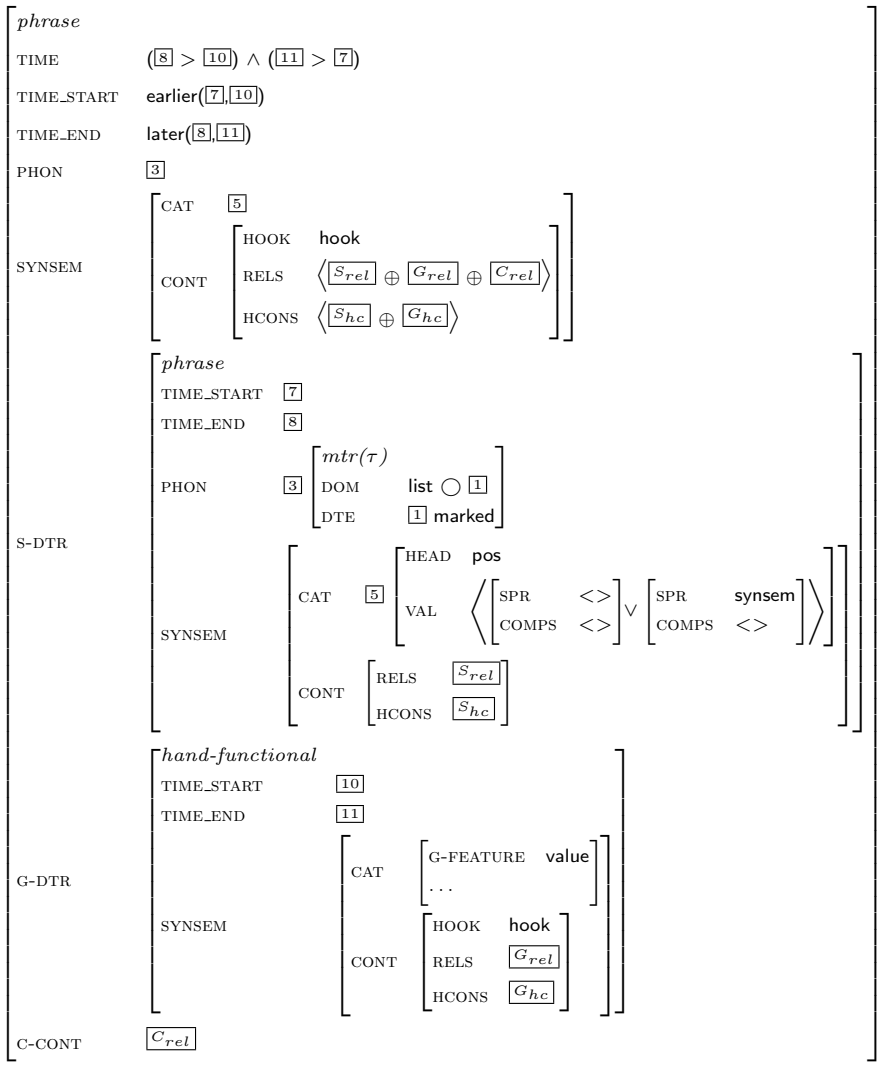
They made everything greasy in the whole room.

- they

The cable unexpectedly and abruptly snapped

- unexpectedly ⇑ whole clause

Example construction rule (simplified)



Conclusion

- Gestural meaning that's derivable from its form is highly underspecified. RMRS flexible enough to formalise this.
- Speech and co-speech gesture should be integrated in the grammar. HPSG flexible enough to formalise this.
- Coherence relations are needed to model gesture because:
  - Underspecified content is resolved via reasoning about the coherence of the gesture performance;
  - Discourse structure constrains what can be gestured now.
- Dynamic semantics constrains gesture reference.

References

R. Engle. *Toward a Theory of Multimodal Communication: Combining Speech, Gestures, Diagrams and Demonstrations in Structural Explanations*. PhD thesis, Stanford University, 2000.

A. Kendon. *Gesture: Visible Action as Utterance*. Cambridge University Press, 2004.

S. Kopp, P. Tepper, and J. Cassell. Towards integrated microplanning of language and iconic gesture for multimodal output. In *Proceedings of ICMI*, 2004.