Formal Models of Narratives

Benedikt Löwe

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symbol
word
sentence
discourse ($\sim$ dialogue)
narrative

Our approach is descriptive, this means that there is a crucial feedback loop between natural language understanding and the formal system. The phenomenon of ambiguity changes its character as you go up the hierarchy: an ambiguous sentence has two readings that are cognitively separate; ambiguity in narratives may lead to formally different representations that still capture the same narrative essence.

When are two stories the same? Karla the Hawk.

M. J. Rattermann and D. Gentner. Analogy and similarity: Determinants of accessibility and inferential soundness. In Proceedings of the Ninth Annual Conference of the Cognitive Science Society (1987), pp. 23-35:

Karla, an old hawk, lived at the top of a tall oak tree. One afternoon, she saw a hunter on the ground with a bow and some crude arrows that had no feathers. The hunter took aim and shot at the hawk but missed. Karla knew the hunter wanted her feathers so she glided down to the hunter and offered to give him a few. The hunter was so grateful that he pledged never to shoot at a hawk again. He went off and shot deer instead.

Once there was an eagle named Zerdia who donated a few of her tailfeathers to a sportsman and he promised never to attack eagles. One day Zerdia was nesting high on a rocky cliff when she saw the sportsman coming with a crossbow. Zerdia flew down to meet the man, but he attacked and felled her with a single bolt. As she fluttered to the ground Zerdia realized that the bolt had her own tailfeathers on it.

Once there was a small country called Bildo that learned to make the worlds smartest computer. One day Bildo was attacked by its warlike neighbor, Gagrach. But the missiles were badly aimed and the attack failed. The Bildon government realized that Gagrach wanted Bildon computers so it offered to sell some of its computers to the country. The government of Gagrach was very pleased. It promised never to attack Bildo again.

Structural alignment.

D. Gentner, A. B. Markman, Analogy—Watershed or Waterloo? Structural alignment and the development of connectionist models of analogy, *in:* Advances in Neural Information Processing Systems (1993)

When are narratives N and N' structurally the same?

1. Develop a formal description language with mathematical structures S corresponding to narratives and a notion of isomorphism between structures,
2. formalize the narratives N and N' into structures S and S',
3. check whether S and S' are isomorphic.

Some criticism.

S. Lam, Affective analogical learning and reasoning, MSc Thesis, University of Edinburgh, 2008.

> *We have shown that [the] lack of inclusion of emotive content [in Gentner's Structure Mapping Engine] has made it psychologically implausible. (p. 38)*

I. Cornelisse, N. Venhuizen, The influence of emotion and sympathy on the evaluation of story similarity, *student project paper*, Universiteit van Amsterdam, 2010.

> *[A] story [with] different emotional content [and a] story ... imply[ing] a different feeling of sympathy ... are both [rated] significantly ... less similar to the Base Story than the True Analogy.*

Toy Examples (1).

Consider a language $\mathbf{TL}_1$ with variables $A = \{a_0, a_1, \ldots\}$ for agents and $O = \{x_0, x_1, \ldots\}$ for objects. We have one *state predicate* `own`(a,x) taking an agent and an object and yielding a *state*. We have five *event predicates* taking agents, objects, states and events and giving an event: `desire`(a,s), `attack`(a,b), `success`(e), `give`(a,b,x), `promise`(a). In addition, we have logical symbols $\neg$ and "IF … THEN …".

The *expressions* of the language $\mathbf{TL}_1$ are states, events, and logical expressions built from states and events with $\neg$ and "IF … THEN …".

A $\mathbf{TL}_1$ structure is a sequence of expressions $\langle p_0, \ldots, p_n \rangle$ of $\mathbf{TL}_1$ such that if $i < j$ and p_i is "IF p THEN q" and $p_j = p$, then $p_{j+1} = q$.

Toy Examples (2).

$\mathbf{TL}_1$: `own(a,x)`, `desire(a,s)`, `attack(a,b)`, `success(e)`, `give(a,b,x)`, `promise(a)`.

Karla the Hawk in $\mathbf{TL}_1$.

$\neg$own(a,x)
desire(a,own(a,x))
attack(a,b)
IF $\neg$own(a,x) THEN $\neg$success(attack(a,b))
$\neg$success(attack(a,b))
give(b,a,x)
own(a,x)
promise(a)

If $P = \langle p_0, ..., p_n \rangle$ and $Q = \langle q_0, ..., q_n \rangle$ are $\mathbf{TL}_1$ structures, they are *isomorphic* if there is are permutations π_A and π_O of the agent and object variables, respectively, such that for any i, ${p_i}^{\pi_A, \pi_O}$ is (logically equivalent to) q_i.

Toy Examples (3).

```
¬own(a,x)
desire(a,own(a,x))
attack(a,b)
IF ¬own(a,x) THEN ¬success(attack(a,b))
¬success(attack(a,b))
give(b,a,x)
own(a,x)
promise(a)
```

Argutt, a wise owl, watched a merchant with a bow with crude arrows that had no feathers. The merchant tried to shoot Argutt, but the shot missed. Argutt realized that the merchant needed the feathers for his arrows, approached him and offered a single owl feather. The merchant accepted the gift and was utterly surprised about a talking owl. He vowed to the gods that he would take his own life so that he could never harm animals again.

Toy Examples (4).

We say that a sequence $\langle p_0, ..., p_n, V\rangle$ is a $\mathbf{TL}_2$ structure if

- $\langle p_0, ..., p_n\rangle$ is a $\mathbf{TL}_1$ structure, and
- $V : \{0, ..., n\} \times A \to \{+, \circ, -\}$ is a function.

We interpret $V(i, a) = +/\circ/-$ as "p_i is positive/neutral/negative for agent a".

If $P = \langle p_0, ..., p_n, V\rangle$ and $Q = \langle q_0, ..., q_n, W\rangle$ are $\mathbf{TL}_2$ structures, they are *isomorphic* if there is are permutations π_A and π_O of the agent and object variables, respectively, such that for any i, $p_i{}^{\pi_A,\pi_O}$ is (logically equivalent to) q_i and $V(i, a) = W(i, \pi_A(a))$ for all i and a.

Toy Examples (5).

Karla the Hawk in TL_2.

	a	b
¬own(a,x)	–	○
desire(a,own(a,x))	○	○
attack(a,b)	○	–
IF ¬own(a,x) THEN ¬success(attack(a,b))	○	○
¬success(attack(a,b))	–	+
give(b,a,x)	+	○
own(a,x)	+	○
promise(a)	○	+

The spectrum of formal systems.

A first attempt at a formulation of the research agenda.

Formal systems together with their notion of *isomorphism* form a continuum of classifications of narratives into equivalence classes. The more expressive a system is, the smaller the equivalence classes are; i.e., fewer narratives are equivalent.

The system we are looking for is

1. simple enough so that humans will not disagree about whether a structure is the correct representation of the essence of a story,
2. expressive enough to capture all features relevant for the notion of structural equivalence we're aiming for.

Theory of Narrative (1).

V. Propp, *Morphology of the Folktale*, Leningrad 1928

> *"Since [narratives are] exceptionally diverse, and evidently cannot be studied at once in [their] full extent, the material must be divided into sections, i.e., it must be classified. Correct classification is one of the first steps in a scientific description. The accuracy of all further study depends upon the accuracy of classification. (p. 5)"*

Propp's formalization of Afanas'ev's *Tale 133*:

$$\beta^1\gamma^2\zeta^1\eta^3\delta^2\theta^3A^1 \left\{ \begin{array}{l} C\uparrow[D^1E^1\mathrm{neg}]^3[D^1E^1\mathrm{neg}]^3F\mathrm{contr} \\ B^4C\uparrow[D^1E^1\mathrm{pos}]^3[D^1E^1\mathrm{pos}]^3 \end{array} \right\} H^1\text{-}I^1K^4\downarrow$$

Two developments:

1. *Narratology*
2. *Story Understanding* ("Computational Models of Narrative")

Theory of Narrative (2): Early *Story Understanding*.

Story Grammars.

D. E. Rumelhart, Notes on a schema for stories, *in:* Representation and Understanding: Studies in cognitive science, 1975

Plot Units.

W. G. Lehnert, Plot Units and Narrative Summarization, *Cognitive Science* 4 (1981), pp. 293–331

Theory of Narrative (3): The Modern Era

TOPs (Thematic Organization Points).

R. C. Schank, Dynamic memory: A theory of reminding and learning in computers and people. 1982.

TAUs (Thematic Abstraction Units).

M. G. Dyer, In-depth understanding: A computer model of integrated processing for narrative comprehension. 1983.

PATs (Planning Advice Themes).

S. Turner, The creative process. A computer model of storytelling. 1994.

The spectrum of proposed formal systems.

The system we are looking for is

1. simple enough so that humans will not disagree about whether a structure is the correct representation of the essence of a story,
2. expressive enough to capture all features relevant for the notion of structural equivalence we're aiming for.

Since the early 1980s, the formal systems used for *Story Understanding* have become increasingly expressive. Even the systems doing *shallow understanding* include more details about the narrative world than are necessary to capture the notion of structural equivalence that we're aiming at.

Proposal. Start from simple systems of the early 1980s or similar systems and add features deemed necessary to capture the notion of structural equivalence.

Comparison of formal systems.

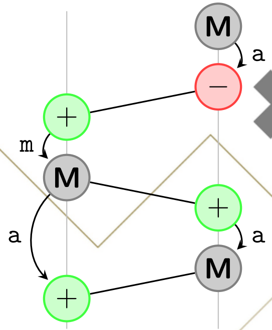
Let Σ be a formal system (with isomorphism relation $\simeq$) and N, N^* be narratives. Suppose that Σ assigns unique structures $\Sigma(N)$ and $\Sigma(N^*)$ to the narratives. Let $N \equiv_\Sigma N^*$ if and only if $\Sigma(N) \simeq \Sigma(N^*)$.

We compare two formal frameworks by studying the granularity of the relation $\equiv_\Sigma$. Fixing two different formal frameworks Σ and Σ^* there are three cases:

- Case 1: Σ is a refinement of Σ^*. This means that for any two narratives N and N^*, if $N \equiv_{\Sigma^*} N^*$, then $N \equiv_\Sigma N^*$.
- Case 2: Σ^* is a refinement of Σ. This means that for any two narratives N and N^*, if $N \equiv_\Sigma N^*$, then $N \equiv_{\Sigma^*} N^*$.
- Case 3: The frameworks are incomparable. This means that there are narratives N_0, N_1, N_2, and N_4 such that $N_0 \equiv_\Sigma N_1$, $N_0 \not\equiv_{\Sigma^*} N_1$. $N_2 \equiv_{\Sigma^*} N_3$, and $N_2 \not\equiv_\Sigma N_3$.

Lehnert's *plot units*

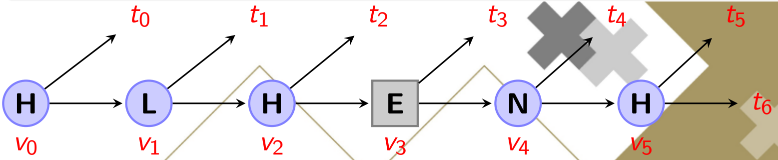
W. G. Lehnert, Plot Units and Narrative Summarization, *Cognitive Science* 4 (1981), pp. 293–331:



Doxastic preference framework

B. Löwe, E. Pacuit, An abstract approch to reasoning about games with mistaken and changing beliefs, *Australasian Journal of Logic* 6 (2008), pp. 162–181

B. Löwe, E. Pacuit, S. Saraf, Identifying the structure of a narrative via an agent-based logic of preferences and beliefs: Formalizations of episodes from CSI: Crime Scene Investigation™, MOCA'09



$S(v_0,\varnothing)(\mathbf{H}) = (t_3, t_0)$; $S(v_1,\varnothing)(\mathbf{L}) = (t_2, t_1)$; $S(v_1,\mathbf{L})(\mathbf{H}) = (t_2, v_3)$;
$S(v_1,\varnothing)(\mathbf{H}) = (t_3, t_2)$; $S(v_2,\varnothing)(\mathbf{H}) = (t_3, t_2)$; $S(v_2,\mathbf{H})(\mathbf{E}) = (t_3, v_4)$;
$S(v_3,\varnothing)(\mathbf{E}) = (v_4, t_3)$; $S(v_4,\varnothing)(\mathbf{N}) = (t_6, t_4)$; $S(v_4,\mathbf{N})(\mathbf{H}) = (t_6, t_5)$;
$S(v_5,\varnothing)(\mathbf{H}) = (t_6, t_5)$

Comparison of PUF and DPF.

- DPF can easily express expectations, PUF can't.
- PUF can identify individual actions as cause of other actions which is difficult for DPF.

We conclude that DPF and PUF are incomparable.

The next step is to look at the separating stories and determine which of the frameworks gives the correct answer. Are expectations of the agents or causal relations relevant features of the structural type of a story?

If yes, add the feature to the system!

A methodological obstacle (1).

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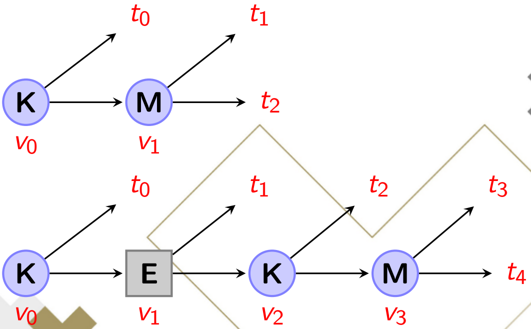
- Kyle kills James,
- Matt enters,
- Kyle tells Matt to “keep [his] mouth shut”,
- Matt follows Kyle’s wish.

A methodological obstacle (2).

- Kyle kills James,
- Matt enters,
- Kyle tells Matt to "keep [his] mouth shut",
- Matt follows Kyle's wish.



Formalizations (1).

Fix a formal framework Σ. A *formalization* $F : N \mapsto F(N)$ is a process assigning to each narrative one or multiple Σ-structures.

The multiplicity is a crucial feature of narrative modelling: it reflects a type of ambiguity that is different from the ambiguity at the word or sentence level:

After the dog barked at John, he bit him.

Note that a *formalization* is necessarily a semi-formal entity, linking an informal object (natural language, video, ...) and mathematical structures.

Formalizations (2).

Let $N \equiv_{\Sigma,F} N^*$ if and only if

- for all $M \in F(N)$ there is an $M^* \in F(N^*)$ such that $M \simeq M^*$, and
- for all $M^* \in F(N^*)$ there is an $M \in F(N)$ such that $M \simeq M^*$.

Fixing two different formal frameworks Σ and Σ^* and corresponding formalisations F and F^*, there are three cases:

Case 1 (Σ, F) is a refinement of (Σ^*, F^*). This means that for any two narratives N and N^*, if $N \equiv_{\Sigma^*,F^*} N^*$, then $N \equiv_{\Sigma,F} N^*$.

Case 2 (Σ^*, F^*) is a refinement of (Σ, F). This means that for any two narratives N and N^*, if $N \equiv_{\Sigma,F} N^*$, then $N \equiv_{\Sigma^*,F^*} N^*$.

Case 3 The frameworks are incomparable. This means that there are narratives N_0, N_1, N_2, and N_4 such that $N_0 \equiv_{\Sigma,F} N_1$, $N_0 \not\equiv_{\Sigma^*,F^*} N_1$. $N_2 \equiv_{\Sigma^*,F^*} N_3$, and $N_2 \not\equiv_{\Sigma,F} N_3$.

Narrative annotations (1).

Study of the quality of *annotations* in corpus linguistics: *inter-annotator agreement*.

R. Artstein, M. Poesio. Inter-coder agreement for computational linguistics. *Computational Linguistics* 34(4): 555–596, 2008:

> *Ever since the mid-[1990s], increasing effort has gone into putting semantics and discourse research on the same empirical footing as other areas of Computational Linguistics. This soon led to worries about the subjectivity of the judgments required to create annotated resources, much greater for semantics and pragmatics than for [other areas of linguistics].*

Narrative annotations (2).

At the level of narrative, this has never been done, not even with the most studied and most well-known formal system: that of Propp.

Joint project with Rens Bod and Sanchit Saraf:

- Create annotation guidelines for Proppian analysis that can be taught to annotators within half an hour.
- Ask trained test people to annotate the Afanas'ev tales and compare to the Proppian analysis.
- Which of the variations are due to intentional or necessary ambiguity; which are due to relevant different interpretations of the annotators?