Getting Deeper Semantics than Berkeley FrameNet with MSFA

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Abstract

This paper illustrates relevant details of an on-going semantic-role annotation work based on a framework called MULTI-LAYERED/DIMENSIONAL SEMANTIC FRAME ANALYSIS (MSFA for short) (Kuroda and Isahara, 2005b), which is inspired by, if not derived from, Frame Semantics/Berkeley FrameNet approach to semantic annotation (Lowe et al., 1997; Johnson and Fillmore, 2000).

1. Introduction

§1.1. presents the current status of our work, presenting our framework called MSFA. §1.2. explains our motivations. Main features of MSFA are presented in §2.1. Relevant details of the proposed annotation scheme under MSFA are presented in §2.3. with some explanations.

1.1. Current status

In (Kuroda and Isahara, 2005b), we defined a framework for fine-grained semantic analysis/annotation called MULTI-LAYERED/DIMENSIONAL SEMANTIC FRAME ANALYSIS (MSFA for short), and produced a small collection of semantic analyses/annotations for Japanese texts taken from *Kyodai Corpus (KC)* (Kurohashi and Nagao, 2003). This was just a first attempt to provide an evaluation version released for free, expecting feedback from users.[1] More annotation work will follow.[2]

The target sentences of the official release were three Japanese newspaper articles, comprising 63 sentences in total, selected from the KC. The English translation of the KC was completed now at NICT, and the Chinese translation is underway. We hoped that our semantic role annotation could be used on a multi-lingual basis if a similar kind of semantic annotation was added to other language's part.

The number of the frames we identified through this annotaion/analysis work comes around 700 in terms of type. Note that, as we will see later, the semantic analysis of a sentence and the identification of frames needed for it are performed at the same time, in a cycle. This distinguishes our work from semantic annotation projects like SALSA Project (Erk et al., 2003), which crucially depend on the pre-existing (and yet completed) BFN database of frames.

In MSFA, we annotate the texts for **semantic roles** differentiated from **semantic types**, an important distinction proposed by (Kuroda and Isahara, 2005a) based on insights from Frame Semantics (Fillmore, 1985; Fillmore and Atkins, 1994).[3] While semantic types can be equated with natural kinds by and large and encoded in a thesaurus effectively, semantic roles can't: they are **situation-specific concepts** highly dependent on culture, seeming to be more responsible for text understanding than semantic types.

1.2. Motivations: Dealing with "deeper" semantics

Semantic annotation has become a trend: it is being practiced in a variety of forms. To name just a few frameworks, we have Berkeley FrameNet (BFN, henceforth) (Baker et al., 1998; Fillmore et al., 2003), PropBank (Kingsbury et al., 2002) and SemCor. For comparison of some of the major frameworks, see (Ellsworth et al., 2004).

When it comes to the task of specifying "deeper" semantics useful to text understanding at realistic levels, BFN looks most appealing because it tries, or at least promises, to provide more specific semantic information than you can get through specification of argument structures of predicates (this is what PropBank aims for) and more interesting information than you can get through WordNet-based word sense disambiguation (this is what SemCor aimed for).

By realistic, we mean it is capable of specifying semantic intuitions that reflect actual mental processing in human brain. Shallow semantic analysis like word sense disambiguations at the level of SemCor is useful, but we still need more to get into realistic text understanding, and without semantic specifications at some reasonably deep levels, understanding of texts at some psychologically realistic levels would be just a fancy, for the reasons specified below.

1.2.1. Need for finer-grained specifications: A case study of a Japanese verb *osou*

(Nakamoto et al., 2005) conducted psychological experiments based on a detailed corpus-based analysis of the Japanese verb *osou*. They analyzed carefully all uses of "*X*-ga *Y*-wo osou" (active) and "*Y*-ga *X*-ni osowareru" (passive form) collected from a Japanese-English alignment data (Utiyama and Isahara, 2003).[4] giving the network analysis specified in Figure 1. The experiments showed that ordinary Japanese were able to easily differentiate at least 15 situations (F01–F15) specified at very concrete levels in

[1]Data access is restricted, however. Users need an account.

[2]Besides this "official" result, some additional semantic analyses/annotations are being done on a volunteer basis in the form of open development available at `http://www.kotonoba.net/~mutiyama/cgi-bin/hiki/hiki.cgi?FrontPage`.

[3]Roughly, the proposed distinction of semantic roles from semantic types corresponds to the distinction of "relational" categories from "object/entity" categories made by Genter and her colleagues (Gentner, 2005; Gentner and Kurtz, 2005; Asmuth and Gentner, 2005). Also, Gentner's "relational schema" category seems to correspond to "(semantic) frame" in the BFN sense, and "(idealized) situation" in our sense.

[4]The result of annotation work is freely available.

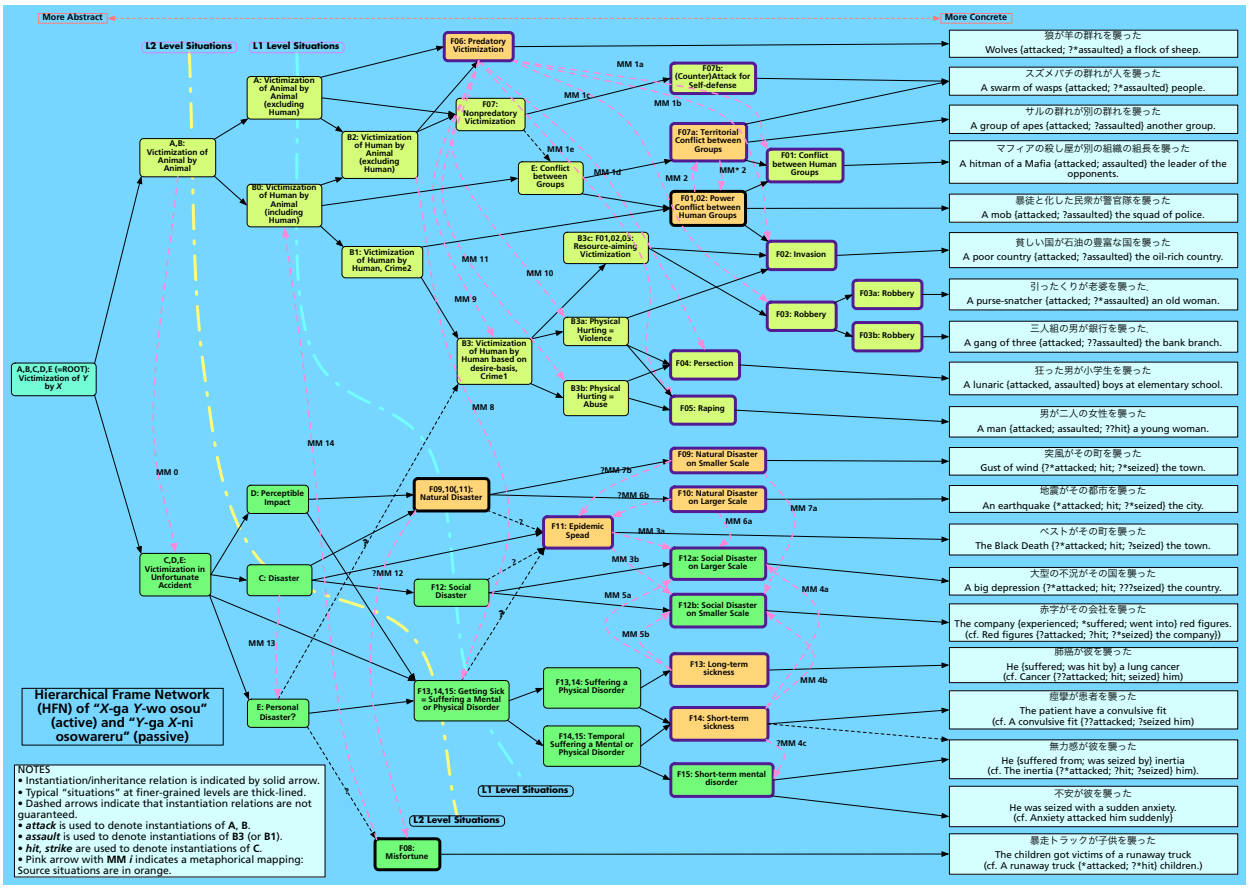


Figure 1: Hierarchical Frame Network Analysis (HFNA) of the situations referred to by *osou*-sentences in Japanese. "L1 and L2 Levels" refer to the semantic classes "L1 and L2" defined in Figure 2.

Figure 1. To set up for this, they tried to specify the full range of the verb's uses in terms of Frame Semantics, coming up with the finer-grained situations (F01–F15).

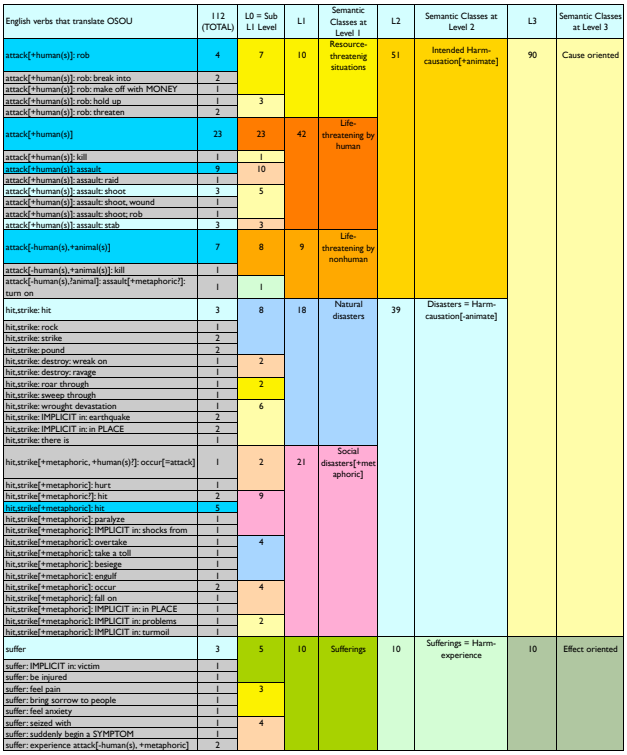
The result reported in (Nakamoto et al., 2005), especially the "frame-lattice" specified in Figure 1, can be used to indicate how much fine-grainedness is needed if we try to annotate **every** use of *osou*.

Note that *osou* is a rather generic verb to denote a situation of victimization of a ⟨ VICTIM ⟩, *Y*, by a ⟨ HARM-CAUSER ⟩, *X*. Its meanings range from "*X* { attack; assault } *Y*" (e.g., *A gang of three* { *attacked; ?assaulted* } *the bank*, which comes close the "core" sense of *osou*, *A purse-snatcher* { *attacked; ??assaulted* } *an old woman*) to metaphorical "*X* { hit; strike } *Y*" (e.g., *The hurricane* { *hit; struck* } *the city*), to further metaphorical "*Y* suffer (from) *X*" (e.g., *The man suffered* { *a damage; from a serious disease* }). For overview, the English translations of the *osou*'s occurrences in the freely accessible component of the JEAD are specified in Table 2.

BFN provides a higher-level description of several coarse-grained classes for the situations specified in Figure 1. Relevant BFN frames are `Attack`, `Cause_harm`, `Cause_impact`, but they turn out to be too coarse-grained, for the reasons specified below, as described in (Kanamaru et al., 2005) in more detail.

An important point is this: (Nakamoto et al., 2005) found that **if activities have different purposes (including "null" value), no matter how "similar" they are in other respects, people tend to categorize/classify them as "different situations"**, and they apparently had no difficulty in performing it. This means something quite ironical to most linguistic/lexicographic analyses: namely, **the use of the same verb (e.g., *osou*) to refer to different situations does not guarantee the sameness of the conceptualizations with and against which situations are described.** Rather, (even) ordinary people have no problem in understanding sentences employing highly "fine-grained" differentiated conceptualizations, at least as fine-grained as the levels of F01–F15. If this is true, it follows that the granularity levels of BFN's `Cause_impact` are unsatisfactory, and it can be easily confirmed by the following fact. `Cause_impact` doesn't distinguish metaphorical and nonmetaphorical uses. For example, *Taifuu-ga Tokyo-wo osotta* ('The typhoon { hit; struck } Tokyo') and *Bouraku-ga shijou-wo osotta* ('The downfall { hit; struck } the market') are not differentiated.

Furthermore, we can find yet finer-grained distinctions in some nonmetaphorical cases of it. For example, *taifuu* ('typhoon') and *toppuu* ('a gust of wind') have different selectional properties: *Taifuu-ga sono mati-wo osotta* ('The typhoon hit the city') sounds natural but ??*Taifuu-ga sono otoko-wo osotta* ('The typhoon hit the man') sounds unnatural. In contrast, ?*Toppuu-ga sono mati-wo osotta* ('A gust of wind hit the city') sounds awkward but *Toppuu-ga sono*



English verbs that translate OSOU	112 (TOTAL)	L0 = Sub L1 Level	L1	Semantic Classes at Level 1	L2	Semantic Classes at Level 2	L3	Semantic Classes at Level 3
attack[+human(s)]: rob	4	7	10	Resource-threatening situations	51	Intended Harm-causation[+animate]	90	Cause oriented
attack[+human(s)]: break into	2							
attack[+human(s)]: rob: make off with MONEY	1							
attack[+human(s)]: rob: hold up	1	3						
attack[+human(s)]: rob: threaten	2							
attack[+human(s)]	23	23	42	Life-threatening by human				
attack[+human(s)]: kill	1	1						
attack[+human(s)]: assault	9	10						
attack[+human(s)]: assault: raid	1							
attack[+human(s)]: assault: shoot	3	5						
attack[+human(s)]: assault: shoot, wound	1							
attack[+human(s)]: assault: shoot; rob	1							
attack[+human(s)]: assault: stab	3	3						
attack[-human(s),+animal(s)]	7	8	9	Life-threatening by nonhuman				
attack[-human(s),+animal(s)]: kill	1							
attack[-human(s),?animal]: assault[+metaphoric?]: turn on	1	1						
hit_strike: hit	3	8	18	Natural disasters	39	Disasters = Harm-causation[-animate]		
hit_strike: rock	1							
hit_strike: strike	2							
hit_strike: pound	2							
hit_strike: destroy: wreak on	1	2						
hit_strike: destroy: ravage	1							
hit_strike: roar through	1	2						
hit_strike: sweep through	1							
hit_strike: wrought devastation	1	6						
hit_strike: IMPLICIT in: earthquake	2							
hit_strike: IMPLICIT in: in PLACE	2							
hit_strike: there is	1							
hit_strike[+metaphoric, +human(s)?]: occur[=attack]	1	2	21	Social disasters[+metaphoric]				
hit_strike[+metaphoric]: hurt	1							
hit_strike[+metaphoric?]: hit	2	9						
hit_strike[+metaphoric]: hit	5							
hit_strike[+metaphoric]: paralyze	1							
hit_strike[+metaphoric]: IMPLICIT in: shocks from	1							
hit_strike[+metaphoric]: overtake	1	4						
hit_strike[+metaphoric]: take a toll	1							
hit_strike[+metaphoric]: besiege	1							
hit_strike[+metaphoric]: engulf	1							
hit_strike[+metaphoric]: occur	2	4						
hit_strike[+metaphoric]: fall on	1							
hit_strike[+metaphoric]: IMPLICIT in: in PLACE	1							
hit_strike[+metaphoric]: IMPLICIT in: problems	1	2						
hit_strike[+metaphoric]: IMPLICIT in: turmoil	1							
suffer	3	5	10	Sufferings	10	Sufferings = Harm-experience	10	Effect oriented
suffer: IMPLICIT in: victim	1							
suffer: be injured	1							
suffer: feel pain	1	3						
suffer: bring sorrow to people	1							
suffer: feel anxiety	1							
suffer: seized with	1	4						
suffer: suddenly begin a SYMPTOM	1							
suffer: experience attack[-human(s), +metaphoric]	2							

Figure 2: English verbs that appear in the translations of the *osou*-sentences in Japanese-English Alignment Data (JEAD) (Utiyama and Isahara, 2003)

otoko-wo osotta ('A gust of wind gust hit the man') sounds fine. All of this suggests that *taifuu* is understood as a relatively large-scale disaster that happens to a relatively large group of people, whereas *toppuu* is understood as a relatively small-scale disaster that happens to an individual.

The same is true of `Cause_harm` and `Attack` but we omit details here for the sake of space.

1.2.2. Need for more effective identification procedure

Based on the observation above, we can state the problem we are facing as follows: if BFN promises to provide "deeper" semantics, how deep should it be? More plainly, are BFN frames "deep enough"? For this matter, our answer is negative, because `Cause_impact`, `Cause_harm`, and `Attack`, provided by BFN, are not detailed enough to specify selectional properties we need to describe to reflect human semantic intuitions. But how is this case, after all?

We believe that **the frame identification procedure adopted by BFN now is not adequate for the purpose of serious, exhaustive semantic annotation/analysis of an unselected text**, no matter how reasonable it may look for the purpose of building a relatively wide-coverage database in a short time. More specifically, we believe that the adequate levels of granularity need to be "discovered" through inductive exploration into real texts, unlike BFN's top-down quick "scans" for frames.

There are more "general" problems that are not particularly applicable to BFN, however. Most seriously, **no evaluation measures are defined to tell whether a given semantic description is "deep enough"** and without such measures, any promise of providing deeper semantics is likely to be ineffective. This means that we definitely need to define a measure for the goodness of frame identification procedure, which provides a "testbed" for evaluating semantic analyses in terms of frames.

There are certain possible choices. At one extreme, one can define as many frames as people can recognize as "different situations", based on the selectional properties for frame-governing verbs. In the case of Japanese verb *osou*, (Nakamoto et al., 2005) showed, as mentioned earlier, that ordinary Japanese were able to easily differentiate at least 15 situations specified at the most concrete levels (F01–F15) in Figure 1, depending on the nature of the `Assailant` (the Agent-class role of `Attack`), `Impactor` (the Agent-class role of `Cause_impact`) and `Harm_causer` (the Agent-class role of `Cause_harm`), especially in terms of their **purposes**. If their claim is adequate, it is implied that HFNA in Figure 1 is not "too detailed." If you want to claim it is, you need justify it on empirical basis, because your claim argues against an empirical result from psychological experiments.

It is possible to say that BFN is more interested in establishing the syntax-semantics interface rather than doing deep enough semantic analysis alone. It sounds like a good excuse, but we are also afraid if it is not "too much for one, not enough for the other."

An important finding by (Nakamoto et al., 2005) is that for *osou*-sentences, the semantic classes of subjects **co-vary** with those of objects. For example, as `F06: Predatory Victimization` in Figure 1 specifies, a ⟨ PREDATOR ⟩ { attacks; ?*assaults; *hits } a ⟨ PREY ⟩. This is why *The wolf attacked the (school of) sheep* contrasts to ?**The wolf attacked the (school of) sardins*, and *The tuna attacked the (school of) sardins* contrasts to ?**The tuna attacked the (school of) sheep*. This piece of deeper semantics, or knowledge of what animal serves as food for what animal, enables us to make such judgments.

Arguably, the semantic **co-variation** (under **co-selection**) among arguments (and adjuncts, too) for a given verb can be used as a good test for differentiation among finer-grained frames/situations, serving as a useful distinctive feature applicable to semantic classification of many other verbs. Later research confirmed this. This means that we can use it as a guideline for frame identification/differentiation. Unfortunately, however, this crucial feature of semantic co-variation is largely ignored, if not totally unrecognized, in BFN now, even though it plays a crucial role in identifying frames/situations.

More importantly, if semantic co-variation accounts for selectional properties of predicates, they ought to be specified somewhere, and we believe their specifications need to be done in terms of frames/situations; or where else? — Do you want it to appear in the entries for WOLF, SHEEP, TUNA, and SARDIN, risking the notorious **frame problem**?

1.3. Why MSFA?

The crucial point here is that there is a sort of "trade-off" between the standardization and expressiveness measures: if you want more standardization, you usually need to sacrifice expressiveness; if you want more expressive-

ness, you usually need to sacrifice its standardization level. Obviously, BFN sets higher priority on the standardization measure, but this is not the only way to go. In a sense, our semantic annotation/analysis was done as an **experiment** to see what would happen if expressiveness is more important. This is why we did what we did.

2. Details of MSFA-based Annotation

In this section, we specify relevant details of the MSFA-based semantic annotation/analysis to clarify what makes it different from BFN-based one.

2.1. Features of MSFA

MSFA-based annotation has the following features:

(1) It is **not presumptive**, in that there are no presupposed frames before doing annotation/analysis, except when the results of a previous analysis are reused. More specifically, frame identification in MSFA is **necessitated** by semantic analysis/annotation itself.

(2) This means that the analysis/annotation needs to be **greedy**, in that as many frames as you need can be identified and added to the analysis, as long as they found necessary for providing deep enough semantic analysis/annotation of a text. Sufficiency is determined by successful specification of semantic covariations among arguments and adjuncts.

(2) It does not assume (at least currently) established definitions for any frames: they are always open to major modifications, and the annotation task is designed so to make it easy to manage.

(3) It is **exploratory**, in that it aims to "discover" frames in a bottom-up, inductive fashion, through the process of "exhaustive" semantic analysis of a text itself.

(4) It is meant to be **exhaustive**, in that every word and multi-word unit are identified as a frame-evoking element: no exception. This means that you are not allowed to ignore certain elements as "uninteresting for our purposes." Rather, you are required to seriously work with capturing the frame-evocation effects by each word within a sentence in a running text.

(5) In this sense, it is **unbiased**, in that identification of frames is not motivated by any specific applications like Machine Translation, QA, Information Retrieval.

(6) Also, it provides semantic analyses/annotations **independent from syntactic parses**, in that it only assumes tokenization, or "shallow parses" in some limited cases only for the sake of simplication. Unlike many other frameworks, it tries to "unground" semantic specifications against syntactic ones. For one, specification of valence-patterns is out of our focus, because it is very likely that other databases will provide such information independently.

(7) This makes annotation **flexible**, in that you are always allowed to add or remove frames. If semantic analysis/annotation depended on certain syntactic parses, it would be a disaster to do such an "editorial" job.

(8) It is meant to be **open**, in that annotation work can be done in the form of open-development. The annotation scheme was so defined that annotators are only required to have a good command of Microsoft Excel, dispensing with special house tools for annotation.[7]

The policy in (2) guarantees that MSFA's aim to provide "unrestricted" and "unbiased" description. It means that it does not avoid the analysis of such "troublesome" cases as metaphors, metonymies, idioms, and other figurative uses of language. Analysis of them can, and it turned out to, be pains-taking, but it's worth doing it. We will be discussing some relevant details in §2.3.3.

2.2. Remarks

One of the anonymous reviewers said that our first attempt, semantic annotations for **only** 63 sentences, was **just** anecdotal. We don't deny it, but we've just started. Please be patient and hold your judgment until you see coming releases. Any great developments started small.

For this, it should be noted that MSFA is designed for an open, distributed development, and researchers are always welcome to participate. It doesn't depend on any house softwares: annotators just need to work on Excel spreadsheets. This, we hope, would "compensate" our small start.

2.3. How Annotation/Analysis Goes in MSFA

2.3.1. Sample MSFAs

For illustration, a sample MSFA of (9), which is `S-ID: 950107210-002` of the KC, is given in Table 3.

(9) アルゼンチンの元サッカー選手、ディエゴ・マラドーナ氏が六日、同国の検察当局に一時身柄を拘束された。

(10) On January 6, Diego Maradona, a renowned former soccer player of Argentina, was temporarily taken into custody by the local prosecutor's office in his country.

As mentioned earlier, MSFA was inspired by the Frame Semantics/BFN approach. Details of MSFA, however, were specified independently of BFN, for reasons specified above. Their main differences are the following:

(11) a. BFN provides standardized frames in the form of a database, whereas MSFA provides an annotation database using frames discovered in a running text in an unselective way.

b. Frames identified using MSFA are more detailed and specific, having more effectiveness than BFN frames in terms of granularity.

This naturally has led to the difference in descriptive density between two frameworks. On average, a sentence has 20+ frames attached to it in the MSFA, drastically more dense if compared to 2 or 3 frames per sentence in the BFN annotation publicized at their Web site.[8]

Despite this, it should be noted that MSFA-based and BFN-based annotations are expected to be compatible, because MSFA should give us a superset of BFN frames.

[7] Of course, the quality control of the annotation work is done by a "committee," managed independently using a Wiki site.

[8] But BFN is not (yet) a project of semantic annotation per se. So, it is kind of unfair to judge BFN from this point alone, as correctly pointed out by one of the reviewers of this article. Saying

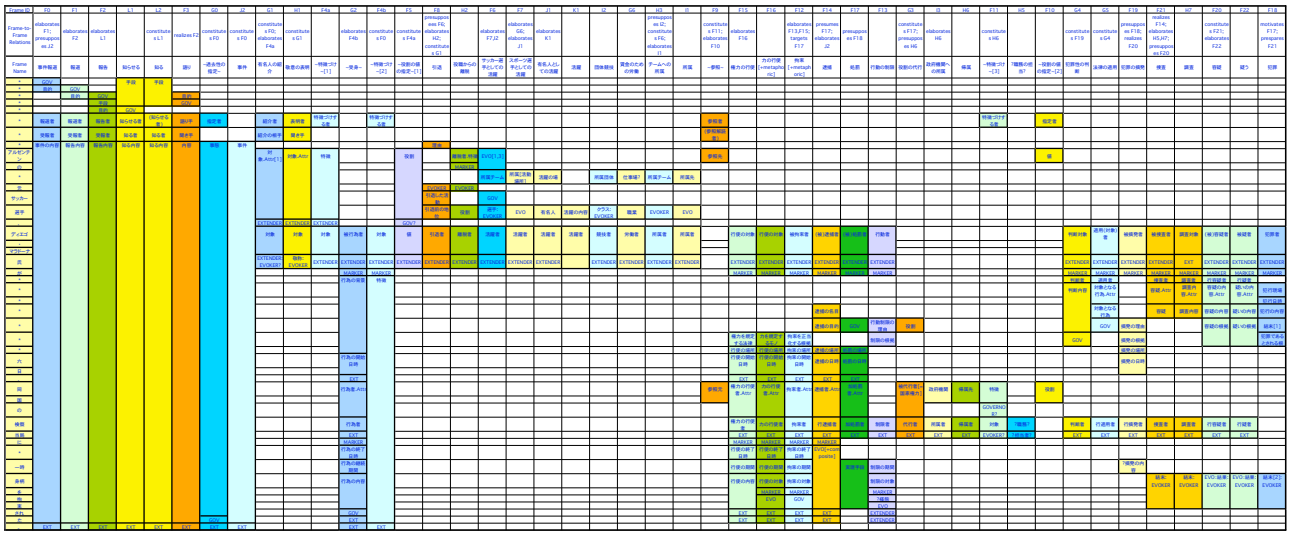


Figure 3: MSFA of (9) [all annotations in Japanese]: Each column specifies a frame; each cell specifies a semantic role with the corresponding segment in the first row as its realization value. Empty, uncolored cells indicate that segments[6] have no specific roles defined against the frames containing them. Relative positioning among frames has no specific meaning, though organized to make the table easy to read.

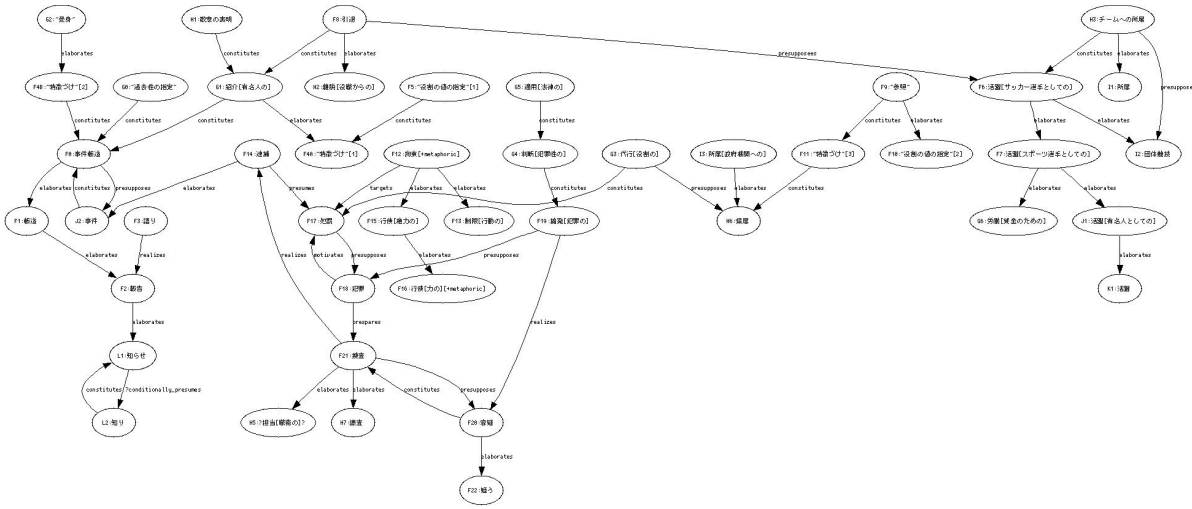


Figure 4: Semantic Frame Network Analysis (SFNA) of (9) automatically generated by GraphViz (a free graphic-generator software) based on the specification in Figure 3, i.e., the MSFA of (9): Each circle specifies a frame (all in Japanese)

2.3.2. Specifying the interrelationships among frames

Specified in Figure 4 is the relationship among frames that constitute the semantic analysis of (9). It specifies how frames are interrelated within a sentence. This is automatically generated from the MSFA in Figure 1.

Listed in (12) according to their relative frequencies are "representative" relationships currently assumed in MSFA,[9] most of which have an equivalent, or analoguous "frame-to-frame relation" in BFN:

(12)
a. "Elaboration" relation: A frame F elaborates another frame G; i.e., F inherits information from G; e.g., ⟨Murder⟩ elaborates ⟨Killing⟩.
b. "Constitution" relation: F constitutes G; i.e., F is part of G. e.g., ⟨Paying⟩ constitutes ⟨Buying⟩.
c. "Presupposition" relation: G presupposes F; e.g., ⟨Buying⟩ presupposes ⟨Selling⟩.
d. "Presumption" relation: F presumes G. This is the reverse of Presupposition; e.g., ⟨Selling⟩ presumes ⟨Buying⟩.
e. "Realization" relation: F realizes G; e.g., ⟨Buying⟩ realizes ⟨Obtaining⟩.
f. "Target/Transfer" relation: F targets G. This is specifically introduced in MSFA to describe the

this, it should be pointed out that there is one remaining problem even if BFN is basically a lexicographic work: **Who is going to supplement a huge amount of "unknown" frames missing in BFN, and how**. We don't believe it can be done automatically.

[9] Other infrequent relations such as "F motivates G" are used.

"figurative uses" of words including metaphor and/or idioms.[10] e.g., ⟨Shooting⟩ targets ⟨Refuting⟩ in sentences like *He **shot** down the counter-arguments from his opponents*.

Some of the relations, such as Presumption, Realization, Transfer do not seem to be defined in BFN.[11]

2.3.3. Encoding "figurative" senses

Real texts contain a lot of problematic cases in which words have "nonliteral" meanings, to which the BFN frame definitions are not easily applicable. Representative, if not all, cases are metaphoric expressions and idiomatic expressions. They pose a serious challenge to semantic annotation/analysis, because, as mentioned above, successful analysis of a metaphorical expression requires clarification of "(conceptual) metaphorical mapping" (Lakoff and Johnson, 1999), and idioms have, for whatever reason, noncompositional, "superlexical" meanings encoded in a distributed fashion. BFN does not explicitly specify how to encode such effects. This is one of the major reasons we defined MSFA independently of BFN. Take *He spilled the political beans* for example, where *political* interrupts *spill(ed) the beans*. This is an example of discontinuous frame-evocation. The multilayered, redundancy-tolerant design allows us to analyze this idiom with the Target/Transfer relation, as in Figure 5. ⟨ PROCECUTOR: *X* ⟩ *take* ⟨ CRIMINAL: *Y* ⟩ *into custody*, appearing in (9) in the passive form *Y was (temporarily) taken into custody* and targeting ⟨Arrest(ing)⟩ (=⟨逮捕⟩) (via ⟨Imprisoning⟩ (=⟨拘留⟩) realizes ⟨Arrest(ing)⟩), is analyzed in this way.

Frame ID (Local)	F1	F2	F3	F4	F5	F8	F6	F7
Frame-to-Frame Relations (Global)	presupposes F3; unsatisfies F3; elaborates F2; targets F5	presupposes F4; unsatisfies F4; targets F5	elaborates F4		presupposes F4; unsatisfies F4; elaborates F8		presupposes F5,F7	
Frame Name (Global)	Spilling	Scattering	Holding	Keeping	Leaking = Failing to Keep Secret	Failing	~Characterization~	Politics
*							Characterizer	
*				GOVERNOR		Failed Activity		
He	Spiller	Scatterer	Holder	Keeper	Leaker	Failer		Politician[+potentially]
spilled	GOVERNOR	GOVERNOR OR EVOKER	EVOKER	EVOKER	EVOKER[1,3]	EVOKER[+composite]		
the	Object.Attr[1]	Object.Attr[1]	Object.Attr[1]	Object.Attr[1]	EVOKER[2,3]: Secret.Attr[1]			
political	Object.Attr[2]	Object.Attr[2]	Object.Attr[2]	Object.Attr[2]	Secret.Attr[2]		Attribute: EVOKER	EVOKER
beans	Object	Object	Object	Object	EVOKER[3,3]: Secret		Object	Issue
.	EXTENDER	EXTENDER	EXTENDER	EXTENDER	EXTENDER	EXTENDER	EXTENDER	EXTENDER

Figure 5: MSFA of *He spilled the political beans*.

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[10] We came to know that a similar solution was adopted in SALSA framework (Burchardt et al., 2006).

[11] It's not easy to establish correspondence between our definitions and the ones given in BFN, because the proper semantics of certain frame-to-frame relations are unclear, need to be refined from the ontological perspective.