Logical Form of Hierarchical Relation on Verbs and Extracting it from Definition Sentences in a Japanese Dictionary

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ABSTRACT

We are studying how to extract hierarchical relation on verbs from definition sentences in a Japanese dictionary. The hierarchical relation on verbs has been dealt with as a binary relation on verbs, but it should be dealt with as logical relation on predicates. We will define the logical form of the hierarchical relation on verbs and then discuss which part of the syntactic structure of the definition sentence represents that relation. We will call the main predicate verb in this part the definition verb. Furthermore we will describe how to semiautomatically select the proper meaning of the definition verb and the proper correspondence between cases of an entry verb and the definition verb in order to extract the hierarchical relation as logical relation.

1 Introduction

The syntactic processing has been playing the main role in a natural language processing system. But we have come to know that we can't construct a practical system with only this processing and that the semantic processing is necessary for it. Inference plays an important role in the semantic processing, we therefore need a large knowledge base about meaning of words and we must treat it as logical relation.

Hierarchical relation between words is inevitable and transitive, and it is a important relation in the large knowledge base. Because inevitable relation holds at any time and the reliability of conclusions inferred from it doesn't fall down and transitive relation can be described efficiently.

There were some researches on extracting the hierarchical relation between words from definition sentences in a ordinary dictionary[1][2][3][4]. But they treated it as only binary relation between words. Verbs correspond to n-ary predicates on entities and we therefore must describe the correspondence between the variables (that is case or syntactic role) of a subordinate verb and ones of its superordinate verb. But this correspondence can't be described if the relation is treated as binary relation between words.

We will propose how to extract the hierarchical relation with a logical form on verbs from definition sentences in a Japanese dictionary. Firstly, we will define the logical form of the hierarchical relation on verbs and then discuss which part of the syntactic structure of the definition sentence represents that relation. We will call the main predicate verb in this part the definition verb. Secondly, we will describe how to semiautomatically select the proper meaning of the definition verb and the proper correspondence between the variables of an entry verb and ones of the definition verb. Lastly, we will report about the result of a experiment to extract the hierarchical relation from the machine readable dictionary IPAL.

A verb will be corresponded to the n-ary predicate according to a pattern of cases (syntactic roles). Considering the polysemy of verbs, each meaning of a single verb must correspond to the distinct predicate. For example, "愛する"(love) as first meaning is used with the form of "x_1 が x_2 を 愛する"(x_1 love x_2) * and corresponds to '愛する$_1(x_1, x_2)$'.

Furthermore, we will not deal with intensional verbs in this paper.

2 Logical Form of Hierarchical Relation on Verbs

Verbs correspond to predicates on entities. If $V^L(\eta_1, \cdots, \eta_n)$ is the subordinate predicate of $V^U(\xi_1, \cdots, \xi_m)$, both predicates have the same arity (i.e. $m = n$), there is a one-to-one correspondence ψ from $\{1, \cdots, n\}$ to $\{1, \cdots, n\}$, and if $V^L(\xi_1, \cdots, \xi_n)$ is true, $V^U(\xi_{\psi(1)}, \cdots, \xi_{\psi(n)})$ is also true at the same time. That is,

$$\forall \boldsymbol{x} \left[V^L(\boldsymbol{x}) \supset V^U(\boldsymbol{x}) \right], \qquad (1)$$

where boldface $\boldsymbol{x}$ stands for a tuple of variables. Strictly speaking, the logical form of the hierarchical relation on verbs is (1).

For example, "飲む$_1$" is the subordinate verb of "摂取する$_1$". To describe this logically,

$$\forall x_1 x_2 \left[飲む_1(x_1, x_2) \supset 摂取する_1(x_1, x_2) \right],$$

where '飲む$_1(\eta_1, \eta_2)$' means that η_1 drink η_2 and '摂取する$_1(\eta_1, \eta_2)$' means that η_1 take η_2.

But there are v^L and v^U such that some arguments in $V^L(\eta_1, \cdots, \eta_n)$ don't correspond to any arguments in $V^U(\xi_1, \cdots, \xi_m)$ or some in $V^U(\xi_1, \cdots, \xi_m)$ don't correspond to any arguments in $V^L(\eta_1, \cdots, \eta_n)$, although v^L is a subordinate verb of v^U. In this case, we conclude that the predicate denoted by $\exists \boldsymbol{y} V^L(\boldsymbol{x}, \boldsymbol{y})$ is a subordinate one of the predicate denoted by $\exists \boldsymbol{z} V^U(\boldsymbol{x}, \boldsymbol{z})$. Therefore, by generalizing (1), we get

$$\forall \boldsymbol{x} \left[\exists \boldsymbol{y} V^L(\boldsymbol{x}, \boldsymbol{y}) \supset \exists \boldsymbol{z} V^U(\boldsymbol{x}, \boldsymbol{z}) \right],$$

that is,

$$\forall \boldsymbol{x}\boldsymbol{y} \exists \boldsymbol{z} \left[V^L(\boldsymbol{x}, \boldsymbol{y}) \supset V^U(\boldsymbol{x}, \boldsymbol{z}) \right]. \qquad (2)$$

We expand (2) further to restrict the domain of $\boldsymbol{z}$, and define the logical form of the hierarchical relation on verbs as follows.

Definition 1 *v^L is a subordinate verb of v^U, if for some $\boldsymbol{N}$*

$$\forall \boldsymbol{x}\boldsymbol{y} \exists \boldsymbol{z} \left[V^L(\boldsymbol{x}, \boldsymbol{y}) \supset \boldsymbol{N}(\boldsymbol{z}) \wedge V^U(\boldsymbol{x}, \boldsymbol{z}) \right],$$

where boldface $\boldsymbol{N}$ stands for a tuple of predicate letters and $\boldsymbol{N}(\boldsymbol{z})$ means $N_1(z_1) \wedge \cdots \wedge N_n(z_n)$.

A small letter, such as n, v, and v^L, stands for a linguistic expression and a capital letter, such as N, V, and V^L, stands for the predicate symbol corresponding to the linguistic expression represented by its small letter.

For example, "潤う$_1$" is a subordinate verb of "帯びる$_1$" because the following formula holds,

$$\forall xy \exists z [潤う_1(y, x) \supset 水分(z) \wedge 帯びる_1(x, z)],$$

where

潤う$_1(\eta_1, \eta_2)$	:	η_2 is irrigated by η_1,
水分 (η)	:	η is moisture,
帯びる$_1(\eta_1, \eta_2)$	:	η_1 take on η_2.

3 Extraction

3.1 Extracting the Hierarchical Expression in a Definition Sentence

Definition 2 *The relation between an entry verb v^e † and its definition sentence s is*

$$\forall \boldsymbol{x} \left[\exists \boldsymbol{y} V^e(\boldsymbol{x}, \boldsymbol{y}) \equiv \exists \boldsymbol{z} S(\boldsymbol{x}, \boldsymbol{z}) \right].$$

For example, the definition sentence for "飲む$_1$"(drink) is "飲物を摂取する$_1$"(to take a drink) and the definition sentence for "潤う$_1$" is "水分をたっぷりと帯びる$_1$"(to take on moisture fully). We get

*Syntactic role is represented by means of a postposition, such as "が" and "を", in Japanese.

†For convenience, we will omit the number of the meaning of an entry verb.

$\forall x_1 x_2$[飲む$_1(x_1, x_2) \equiv$
飲物 $(x_2) \wedge$ 摂取する$_1(x_1, x_2)$],

$\forall x$[$\exists y$潤う$_1(y, x) \equiv$
$\exists z$[水分$(z) \wedge$ たっぷりと帯びる$_1(x, z)$]],

where

飲む (η_1, η_2) : η_1 drink η_2,
飲物 (η) : η is a drink,
摂取する (η_1, η_2) : η_1 take η_2,
潤う$_1(\eta_1, \eta_2)$: η_2 is irrigated by η_1,
水分 (η) : η is moisture,
たっぷりと帯びる$_1(\eta_1, \eta_2)$:
η_1 take on η_2 fully.

We call the main predicate verb of a definition sentence the definition verb. If the definition sentence of a entry verb v^e corresponds to

$$N(\eta) \wedge V^d(\eta), \quad (3)$$

then we can easily derive the hierarchical relation between v^e and its definition verb v^d from Definition 2. In this paragraph, we assume that the meaning of the definition verb has been selected correctly and we will omit the number of the meaning of definition verbs. How to select it will be given in **3.2**.

A definition sentence does not always correspond to the logical form as (3). But if we can get the sentence s^d which is a part of the definition sentence s and corresponds to the logical form as (3) and $S \supset S^d$, then we can also derive the hierarchical relation between the entry verb and the definition verb. We call s^d the hierarchical expression in a definition sentence (**HED**). Now, we will discuss which part of the syntactic structure of the definition sentence is **HED**.

Definition 3 *We get rid of modifiers out of a simple sentence s. We call the rest of s the kernel sentence s^k of s.*

Since there isn't a expression corresponding to a universal quantifier in the definition sentence of a verb, we can conclude the following characteristic.

Characteristic 1 *If s^k is the kernel sentence of a simple sentence s, then $S \supset S^k$ and the logical form of S^k is (3).*

For example, the kernel sentence of "体の痛みを一時的に消す"(to kill a pain in the body temporally) is "痛みを消す"(to kill a pain) and its logical form is

$$\text{痛み}(\eta_2) \wedge \text{消す}(\eta_1, \eta_2),$$

and the following formula holds,

$$\forall \eta_1 \eta_2 \eta_3 [S(\eta_1, \eta_2, \eta_3) \supset \text{痛み}(\eta_2) \wedge \text{消す}(\eta_1, \eta_2)],$$

where $S(\eta_1, \eta_2, \eta_3)$ is the formula corresponding to "体の痛みを一時的に消す" and means that η_2 is a pain, η_3 is a body, and η_1 kill η_2 in η_3 temporally. '痛み (η)' means that η is a pain. '消す (η_1, η_2)' means that η_1 kill η_2.

There is a sentence s which satisfies the following characteristic.

Characteristic 2 *A sentence s includes a sentence s' and $S \supset S'$.*

If the definition sentence s of a verb is complex, then s satisfies Characteristic 2 and s' is its main clause. For example, the main clause of the sentence "何かがかぶさるように付着する" (something adheres to X as it covers X) is "何かが付着する"(something adheres to), and it corresponds to the following formula,

$$\text{何か}(\eta_1) \wedge \text{付着する}(\eta_1, \eta_2),$$

and the following formula holds,

$$\forall \eta_1 \eta_2 [S(\eta_1, \eta_2) \supset \text{何か}(\eta_1) \wedge \text{付着する}(\eta_1, \eta_2)],$$

where $S(\eta_1, \eta_2)$ is the formula corresponding to "何かがかぶさるように付着する" and means that something η_1 adhere to η_2 as η_1 covers η_2, '何か (η)' means that η is something, and '付着する (η_1, η_2)' means that η_1 adhere to η_2.

Meaning of the compound sentence s, in which two sentences (s_1,s_2) are connected by a conjunction corresponding to 'and' in English, is either '$S_1 \wedge S_2$' or '$after\ S_1,\ S_2$'. Therefore, an operator needs to decide the relation between s_1 and s_2. In the former case, s satisfies Characteristic 2 and s' can be both s_1 and s_2. For example, a sentence "何かを投げて勢いよく接触させる"(to throw something and have it touched hard) consists of two sentences. One is "何かを投げる" (to throw something), the other is "勢いよく接触させる"(to have it touched hard), and two sentences correspond to following formulae respectively,

$$何か(\eta_2) \wedge 投げる(\eta_1, \eta_2),$$

$$勢いよく接触させる(\eta_1, \eta_2, \eta_3).$$

And two sentences are simultaneous. So following formulae hold,

$$\forall \eta_1 \eta_2 \eta_3 [S(\eta_1, \eta_2, \eta_3) \supset 何か(\eta_2) \wedge 投げる(\eta_1, \eta_2)],$$

$$\forall \eta_1, \eta_2 \eta_3 [S(\eta_1, \eta_2, \eta_3) \supset 勢いよく接触させる(\eta_1, \eta_2, \eta_3)],$$

where $S(\eta_1, \eta_2, \eta_3)$ is the formula corresponding to "何かを投げて勢いよく接触させる"and means that η_1 throw η_2 and have η_2 touched hard to η_3. '何か (η)' means that η is something. '投げる (η_1, η_2)' means that η_1 throw η_2. '勢いよく接触させる (η_1, η_2, η_3)' means that η_1 have η_2 touched hard to η_3.

To apply Characteristic 2 repeatedly, we conclude that there is a definition sentence s which include a simple sentence s' and $S \supset S'$ and that the kernel sentence of s' is **HED**. For example, the sentence s "あるものをまっすぐにするためにその物の両端を持って両方向に力を加える" (to hold both ends of something and apply force to both sides in order to make it straight) is complex. It therefore satisfies Characteristic 2 and $S \supset S_1$, where s_1 is its main clause "その物の両端を持って両方向に力を加える" (to hold both ends of something and apply force to both sides). s_1 is a compound sentence and is composed of s_2 "その物の両端を持つ" (to hold both ends of something) and s_3 "両方向に力を加える" (to apply force to both sides) and two sentence is simultaneous. s_1 therefore satisfies Characteristic 2 and $S_1 \supset S_2$ and $S_1 \supset S_3$. Therefore, $S \supset S_2$ and $S \supset S_3$. Because s_2 and s_3 are simple sentences, the kernel sentences of s_2 and s_3 are **HED**s. When the definition sentence is simple, its kernel sentence is **HED**.

If we decide the proper meaning of the definition verb and the proper correspondence from cases of v^e to cases of v^d correctly, we conclude

$$\forall xy \exists z [V^e(x, y) \supset N_x(x) \wedge N_x(z) \wedge V^d(x, z)]. \quad (4)$$

We can get a hierarchical relation between v^e and v^d as follows from (4),

$$\forall xy \exists z \left[V^e(x, y) \supset N_x(z) \wedge V^d(x, z)\right].$$

3.2 Necessary Condition and Heuristic

In this paragraph we supposed that an entry verb v^e has **HED**.

What we call the *selectional restriction* has been used to narrow down candidates for syntactic structure in the syntactic processing. It is the restriction about the semantic category of a noun phrase which a certain verb can take as a certain case. The semantic category has been called the *semantic marker* or *semantic primitive*. For example, semantic categories of the subjective noun phrase and the objective noun phrase for the verb "飲む"(drink) must be 'animal' and 'liquid' respectively. We use this information to semiautomatically select the proper meaning of v^d and the proper correspondence from cases of v^e to cases of v^d. The information is mentioned in the Japanese dictionary we used for the experiment of extraction.

The restriction that if a verb v_k can take a noun phrase with a case c the semantic category of the noun phrase is D is expressed logically as follows,

$$\forall x \left[V_k(x) \supset D(x_i)\right], \quad (5)$$

where x_i is the argument corresponding to the case c, and k is the meaning number of v. We call D in (5) the domain for c of v_k. For example,

$$\forall \eta_1 \eta_2 [飲む_1(\eta_1, \eta_2) \supset animal(\eta_1) \wedge liquid(\eta_2)],$$

where '$飲む_1(\eta_1, \eta_2)$' means that η_1 drink η_2.

If the semantic category of a noun n is D,

$$\forall x [N(x) \supset D(x)]. \quad (6)$$

We call D in (6) the domain for n.

If the k-th meaning is proper as v^d in the definition sentence of v^e and the correspondence from i-th case of v^e to j-th case of v^d_k is correct, then the following formula holds,

$$\forall \cdots x \cdots [V^e(\cdots, \overset{\underset{\downarrow}{i}}{x}, \cdots) \supset \cdots \wedge N(x) \wedge \cdots \wedge V_k^d(\cdots, \underset{\underset{j}{\uparrow}}{x}, \cdots)] . \quad (7)$$

Assumption 1 *We assume $\exists x V(x)$ is true for each verb v and $\exists x N(x)$ is true for each noun n.*

We conclude

$$\exists x \left[D^e(x) \wedge D^n(x) \wedge D^d(x)\right] \quad (8)$$

from $\exists x V^e(x)$ (Assumption 1) and (7), where

$$\forall \eta \, [V^e(\cdots, \eta_i, \cdots) \supset N^e(\eta_i)] ,$$

$$\forall \eta \left[V_k^d(\cdots, \eta_j, \cdots) \supset N^d(\eta_j)\right] ,$$

$$\forall \eta \, [N(\eta) \supset D^n(\eta)] .$$

We establish (8) as the necessary condition in which the correspondence is valid. We check (8) with $\exists x N(x)$ (Assumption 1) and the relation between domain predicates.

Necessary Condition *If the k-th meaning is proper as v^d in the definition sentence of v^e and the correspondence from i-th case of v^e to j-th case of v_k^d is correct, then*

$$\exists x \left[D^e(x) \wedge D^n(x) \wedge D^d(x)\right] ,$$

where D^e is the domain for i-th case of v^e and D^d is one for j-th case of v_k^d and the noun of j-th case of v_k^d in the definition sentence is n and the domain for n is D^n.

The meaning of an entry verb v^e is defined by using the definition verb v^d. Then, the less the number of the variables appearing either only in v^e or only in v^d (i.e. $(size\ of\ tuple\ y) + (size\ of\ tuple\ z)$ in the formula (4)), the more v^d restricts the meaning of v^e. An editor of a dictionary would select such a definition verb. We therefore establish the following heuristic.

Heuristic *The less the number of the variables appearing either only in v^e or only in v_k^d, the more we have chance of correct selection for meaning of v^d and the correspondence of the variables.*

3.3 Example of Extraction

In this paragraph the method how to extract the hierarchical relation on verbs will be introduced. We suppose following definitions about "愛する" and "持つ".

愛する

I [(*human*) が (*human*) を] ⟵ ⓐ
とても好きだという気持ちを持つ. (to experience a strong feeling of fondness)

....

持つ

I [(*human*) が (*hand*) に (*concrete*) を]
手に何かを持つ. (to have something with one's hand)

II [(*human*) が (*human*) に (*mental*) を]
誰かに対してある感情を抱く. (to experience a feeling toward somebody)

III [(*all_entities*) が (*abstract*) を]
何らかの属性や設備を有する. (to have some property or equipment)

ⓐmeans that "愛する$_1$" is used with the form of "np_1 が np_2 を 愛する" and the semantic category of np_1 and np_2 must have '*human*'. We get the following knowledge about domain of words.

$$\forall \eta[\text{愛する}_1(\eta_1, \eta_2) \supset human(\eta_1) \wedge human(\eta_2)],$$
$$\forall \eta[\text{持つ}_1(\eta_1, \eta_2, \eta_3) \supset [human(\eta_1) \wedge \wedge hand(\eta_2) \wedge concreat(\eta_3)]],$$
$$\forall \eta[\text{持つ}_2(\eta_1, \eta_2, \eta_3) \supset [human(\eta_1) \wedge \wedge human(\eta_2) \wedge mental(\eta_3)]],$$
$$\forall \eta[\text{持つ}_3(\eta_1, \eta_2) \supset all\_entities(\eta_1) \wedge abstract(\eta_2)],$$
$$\forall \eta[\text{気持ち}\ (\eta) \supset mental(\eta)].$$

'*all_entities*' expresses the set of all entities. We suppose the following relation between domain predicates,

$$\forall \eta[human(\eta) \vee hand(\eta) \supset concrete(\eta)],$$
$$\forall \eta[mental(\eta) \supset abstract(\eta)],$$
$$\forall \eta[concrete(\eta) \vee abstract(\eta) \supset all\_entities(\eta)],$$
$$\neg\exists \eta[concrete(\eta) \wedge abstract(\eta)],$$
$$\neg\exists \eta[human(\eta) \wedge hand(\eta)].$$

We parse the definition sentence "とても好きだという気持ちを持つ" for the entry verb "愛す

る $_1$", and we find this sentence is simple and its kernel sentence "気持ちを持つ" is **HED**. We narrow down candidates for the meaning of the definition verb "持つ" on parsing by *selectional restriction.* Meanings of "持つ" that satisfy *selectional restriction* are II and III. Since we can infer

$$\exists x[human(x) \wedge all\_entities(x)]$$

from Assumption 1 and the relation between domain predicate, the correspondence from the first case of "愛する$_1$" to the first case of "持つ $_3$"satisfies the necessary condition described in paragraph **3.2**. Since we can infer

$$\neg\exists x[human(x) \wedge mental(x) \wedge abstract(x)],$$

the correspondence from the first case of "愛する $_1$" to the second case of "持つ $_3$"does not satisfy the necessary condition. After all, for "持つ$_2$" and "持つ$_3$", partial one-to-one correspondences which satisfy the necessary condition are

$$\begin{array}{lll} 持つ_2: & a.\{\}, & \\ & b.\{<1,1>\}, & c.\{<1,2>\}, \\ & d.\{<2,1>\}, & e.\{<2,2>\}, \\ & f.\{<1,1>,<2,2>\}, & \\ & g.\{<1,2>,<2,1>\}, & \\ 持つ_3: & h.\{\}, & \\ & i.\{<1,1>\}, & j.\{<2,1>\}, \end{array}$$

For example, the correspondence g means that the first case of "愛する$_1$" corresponds to the second case of "持つ$_2$" and the second case of "愛する$_1$" corresponds to the first case of "持つ $_2$".

Because the number of the variables which appear either only in the entry verb or in the definition verb for the correspondence g is 1 and one for the correspondence i is 2, the pair of "持つ$_2$" and the correspondence g is prior to the pair of "持つ$_3$" and the correspondence i by the heuristic. The pair of "持つ$_2$" and the correspondence f and the pair of "持つ$_2$ and the correspondence g are given the highest priority by the heuristic after all.

It is decided by a operator that the second meaning of 持つ and the correspondence f are proper, and we get

$$\forall x \exists z[愛する_1(x_1,x_2) \supset 気持ち(z) \wedge 持つ_2(x_1,x_2,z)].$$

4 Experiment of Extraction

We have experimented on extracting the hierarchical relation using the machine-readable dictionary **IPAL** (IPA : Information-technology Promotion Agency, Japan ; IPAL : IPA Lexicon of the Japanese language for computers). 861 verbs and 3379 meanings are contained in this dictionary. The definition sentence of an entry verb and the pattern of cases for the entry verb and the domain for each of the cases of the entry verb are given in this dictionary (see Appendix). And we can also get the domain for a noun from this dictionary.

We made a lexical functional grammar which outputs the logical form of **HED** as a feature. We parsed the definition sentences and got 1709 **HEDs** whose main predicate verb are given as an entry verb in this dictionary with this grammar. We have extracted the hierarchical relations on verbs from 1288 **HEDs**. The average number of candidates which are given the highest priority by the heuristic described in paragraph **3.2** is 4.6 and there is the correct solution in 4.6 candidates at the rate of 70.4%. The number of meanings of verbs in the highest layer in the hierarchy is 288, and the average level in the hierarchy is 2.7. Maybe this value is so little. We think in this point since IPAL is a basic verb dictionary its entry verbs are in a comparatively high ordinate in hierarchy of all verbs.

5 Conclusion

We have defined the logical form of the hierarchical relation on verbs and have described how to extract it from definition sentences in a Japanese dictionary.

The method described in this paper is for a Japanese dictionary, but it can be applied to other languages dictionary, too.

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Appendix

A.1 Example of Contents of IPAL

《見出し》もつ　　　　　　　　《通番》００１
《Ｎｏ》００５《枚数》０１２《意味》何かに対して、ある感情を抱く。《類義》抱く《分名１》（感覚・疲労・睡眠など）《分番１》（２．３００）《分名２》（感想）《分番２》（４１１ｂ）《意味分類》動作（動き），生理・心理，知覚・思考《表記》持（も）つ《活用》五段《語幹》ｍｏｔ《自他》他《派可》もてる《派使》もたす《文型》Ｎ１ガ　Ｎ２ニ　Ｎ３ヲ《文１》私は　将来に希望を　持っている。《文２》彼は　相手のやり方に　反感を　持った。《述語素》Ｏ２，ＮＧ２，Ｏ１《格１》ガ《素１》ＨＵＭ／ＯＲＧ《名１》彼／政府《格２》ニ《素２》ＣＯＮ／ＡＢＳ《名２》自分、彼女、新人、相手国、車、花、山／生活、将来、計画、政府のやり方《格３》ヲ《素３》ＭＥＮ《名３》自信、関心、期待、不満、ゆとり、希望、確信、不信感、疑問、悩み、恐れ、好感、反感、敵意《ヴ１》ニ使役《ヴ２》直受，間受，尊敬《ヴ３》ヲ《ヴ４》ニヨッテ《ヴ７》能動《テ１》未来《テ２》結果残存《テ３》テシマウ，カケル，ハジメル，ダス，ツヅケル《ム１》命令《ム２》意志・勧誘《ム３》タイ・タガル，ナサイ，ナ（禁止）《ム４》３ａ《マナ》マス，ナイ《慣用》根に〜。

《…》 expresses what the filed following it means. 'もつ' is a entry. '持つ' is the notation of the entry with Chinese character. '何かに対して，ある感情を抱く。' is a definition sentence. '005' following 《Ｎｏ》 represents the definition sentence corresponds the fifth meaning of 'もつ（持つ）'. The Japanese word following 《格 i》 and symbols following 《素 i》 represent a pattern of the cases for 持つ_5 and the domain for each case of the verb. That is, '持つ_5' is used with the form 'NP_1 が NP_2 に NP_3 を持つ', and the semantic category of NP_1 is 'human' or 'organization', and one of NP_2 is 'concrete object' or 'abstract object', and one of NP_3 is 'mental object'. We can get

$$\forall x[\text{持つ}_5(x_1,x_2,x_3) \supset [human(x_1) \vee organization(x_1)] \wedge [concrete(x_2) \vee abstract(x_2)] \wedge mental(x_3)]$$

from these informations. Japanese words following 《名 i》 are example of NP_i. We can get the domain for nouns from these informations. For example, we can get

$$\forall x[\text{政府}\,(x) \supset organization(x)],$$

where '政府' means 'government'. We used the above informations.

A.2 A Example of Extracted Relations

$$\text{示す}_3(x_1,y,x_2,x_3) \supset \text{表わす}_3(x_1,x_2,x_3)$$

$$\text{出す}_{17}(x_1,x_2,y) \supset \exists z[[\text{しぐさ}\,(z) \vee \text{表情}\,(z)] \wedge \text{表わす}_3(x_1,x_2,z)]$$

$$\text{嘆く}_1(x_1,x_2) \supset \exists z\,\text{表わす}_3(x_1,x_2,z)$$

$$\text{掲げる}_3(x_1,x_2) \supset \exists z\,\text{示す}_3(x_1,z_1,x_2,z_2)$$

$$\text{掲げる}_4(x_1,x_2,x_3) \supset \exists z[\text{人}\,(z) \wedge \text{示す}_3(x_1,z,x_3,x_2)]$$

$$\text{表わす}_2(x_1,x_2,x_3) \supset \text{出す}_{17}(x_1,x_2,x_3)$$

$$\text{漏らす}_2(x_1,x_2,y) \supset \exists z[[\text{声}\,(z) \vee \text{表情}\,(z)] \wedge \text{出す}_{17}(x_1,z,x_2)]$$

$$\text{示す}_2(x_1,x_2,x_3) \supset \text{表わす}_2(x_1,x_2,x_3)$$

$$\text{見せる}_{10}(x_1,x_2,x_3) \supset \text{示す}_2(x_1,x_2,x_3)$$