Sortal Incorrectness in Conceptual Graphs

Jonathan C. Oh and Sang-Ok Seo

Sortal incorrectness is an age-old problem to philosophers and linguists. It is an important issue to knowledge representation researchers. This paper is an exercise based on those examples used to illustrate sortal incorrectness in various papers cited in the reference. We analyse these example sentences using Sowa's conceptual graph theory. We outline in this paper how sortally incorrect knowledge items are kept from being admitted into a knowledge base. In the process we make some rather interesting observations concerning the organization of concept catalogue and the treatments of external negation and adverb-related sortal incorrectness.

0. Introduction

Sortal incorrectness is an age-old problem to philosophers and linguists. It is an important issue to knowledge representation researchers. In parsing natural language sentences, sortal incorrectness can be taken advantage of as an important guiding principle. Particular approaches to treatment of sortal incorrectness have different implications toward handling metaphors, a very difficult but essential problem in knowledge representation. This paper is an exercise based on those example sentences used to illustrate sortal incorrectness in various papers. By the data sentences drawn in such a manner instead of some homogeneous applications, we attempt to reveal as complete a picture as possible of the task that is involved.

The theoretical framework for the exercise is that discussed in Sowa 1984. We will outline how we conjecture Sowa's program will go in avoiding the type of mismatches discussed here. We will then comment on and propose some essential modifications to Sowa's theory so that sortal incorrectness could be handled in a knowledge based system or in a knowledge representation context as a whole. We will assume that the main source of knowledge is natural language (NL) texts, which will be translated by some natural language processing system (NLPS) into a knowledge base

(KB). Such a knowledge base may be used in diverse applications. Some examples are information retrieval, DB frontends, question answering, and help systems. Let us take question answering for example. NLPS will translate the query into a knowledge representation language (KRL). The reasoning component (IE, inference engine) of the knowledge based system (KBS) then will search through the KB for the answers for the query, which can be translated back into an NL by NLPS. At various stages of the translation from an NL into a KRL the sortal incorrectness will be exploited. By the time a knowledge item or a query has been translated into the representation language, sortally incorrect NL expressions, i.e. those NL expressions whose translations are sortally incorrect will have been all rejected and their translations will not ever be admitted into KB. At all times KB will consist of sortally correct KRL expressions only. For those various tasks mentioned above, the KBS is equipped with a lexicon, a concept catalogue, a relation set, and a type hierarchy for the concepts and relations.

1. Characterization of Sortal Incorrectness

First we will try to characterize the nature of sortal incorrectness. Sortal incorrectness and truth value falsehood should be clearly distinguished. Consider, for example, the predicate 'countable'. While it is true only of a subset of entities, the sortal range is the entire set of entities. It is false to say that a liquid or gas or mass object such as sugar and salt in powdered form is countable but it is true and sortally entirely correct to say that such are not countable. We feel it is important to establish right off that sortal incorrectness is a semantic phenomenon, not a syntactic one. Thus while it is true that sortal incorrectness can arise due to some mismatches between a predicate on the one hand and its subject or object or even its adverb on the other, it is not the words or phrases themselves that are responsible for sortal incorrectness but their denotations and mismatches between these denotations. Thomason (1972) gives interesting arguments to show that sortal incorrectnesses arise on a semantic level, not on a syntactic level. If someone says that what he is thinking of is shiny, the sortal correctness of what he says depends on what he is thinking of. In Sowa's terms, we conjecture that sortal incorrectness can best be captured in terms of constraints on the type pairing over a given relation. In Sowa (1984), the

world knowledge needed for sortal correctness decision can be organized in a canonical basis or as conceptual schemata. All canonical graphs—sortally correct graphs—can be derived from canonical basis by formation rules. The canon contains the information necessary for deriving a set of canonical graphs. It has four components; a type hierarchy T, a set of individual markers I, a conformity relation R that relates labels in T to markers in I and a canonical basis B.

2. Previous Analysis

We will discuss one particular analysis of sortal incorrectness and the reason for the selection is due to its thoroughness and reasonableness. The author's intuition and assumptions match ours most closely. Lappin (1981) presents an account of sortal incorrectness that is based on the model-theoretic semantics. It satisfies the four requirements he lays out for an adequate theory of sortal incorrectness. The first requirement is that a theory must characterize a sentence to be sortally incorrect which is syntactically well-formed but lacks truth-value in all possible worlds. The second requirement is that a theory be able to distinguish between sortal incorrectness and other sorts of truth-valueless sentences, such as sentences which lack truth-values by not fulfilling presuppositions. The third requirement is that a theory must be able to capture inferences which depend on sortal factors. Finally it must be able to handle sortal incorrectness that arises from the use of adverbs.

Important features of his analysis relevant to our discussion are reviewed here. For the full details, the reader is referred to the book. A constant denotes the same object in all possible worlds. A definite description refers to a unique object that satisfies the description in a given possible world, possibly a different object in a different world. The sortal range of an n-ary predicate is the total union of the denotations of the predicate under a given interpretation in all possible worlds. A sentence 'P al a2 ... an' is sortally incorrect if and only if the denotations of the arguments in the given order is not in the set of n-tuples which constitutes the sortal range of the predicate, in other words, if the sentence is not true in any of the possible worlds. This is a perfectly allowable model-theoretic interpretation of the Sowa's program we will discuss below.

3. Negations and Metaphors

In determining sortal ranges for a given predicate, certain negations and metaphors can confuse the matters so we will make some comments here on them. We wrote above that the sortal range of a predicate is a supertype of its truth range. Clearly the sort of things which can be counted is a proper subset of the sort of things for which countability can be either asserted or denied. Of the relative complement of the truth set of a predicate with respect to its sortal range it can be truthfully and sortally correctly said that an object is not in that truth set. Such negation is the so-called internal negation. Thus we can truthfully and sortally correctly say as we mentioned above that salt is not countable. We maintain that the statement that salt is countable is sortally correct, only incorrect in truth valve.

Compare this with another type of negation, the so-called external negation. When one says that the theory of relativity does not have a color, it is somewhat of a different nature from when one says that little Tommy's face has no color. In the latter we assume that the face can and perhaps should have a color but unfortunately does not happen to at this moment whereas in the former we are introducing a law of a kind, that a theory is not the sort of thing that can have a color. We claim that we do not here have two different types of negation, only two different levels of statements that are being negated. In Sowa's terms, the conceptual graphs in the canonical basis are rules or templates or types of statements whose applications, instances or tokens may be asserted or denied (an internal negation). When a negation is applied to a rule/template/type, we see a case of the so-called external negation. We propose a notation here to distinguish these templates from their instances. In order to establish that only concrete things can be blue we introduce into the canonical basis the [BLUE] ⇐ (ATTR) ⇐ [CONCRETE]. For an actual KB item we use the usual CG notation, e.g. [BLUE]←(ATTR)←[EYE: {*}]→(PART)→[CAT: storge].

This external negation has also been called the appropriateness negation. And this is in contrast with the truth-value negation. These appropriatenesses are relative to various kinds of rules, some social and others linguistic, semantic and pragmatic, some language and culture specific and others with degrees of language and culture independence. There are social rules

having to do with the use of honorific expressions in some cultures applied to those considered to be socially superior. Some of these rules can be cast in the negative, the negation being the external one. There are rules dealing with lexical uses, presuppositions associated with certain lexical items. If one emphatically rejects a claim that a person has stopped beating his wife, aware that in fact he is not even married nor the type of person who would carry out such a degraded act if he had been married, the negation is an expression of a protest toward the use of the term 'stop' which carries the presupposition that he did in fact beat his wife in the time past, thus showing the inappropriateness of the use of the term in this context. One can go on listing quite a few sorts of rules and demonstrate the use of the external negation. We hope that this paragraph makes it clear why the external negation is called the inappropriateness negation, adding to the feasibility of the analysis of the external negation proposed here. In addition we would like to make a comment in passing that might be worth some thought, namely that what is traditionally considered to be cases of sortal incorrectness appears to be a special case of a rather general set of inappropriateness classes.

One would like to say that the sortal range of 'excitable' is animate things. But we sometimes say that certain chemicals are excitable in the sense that with a slight shake they can explode. We maintain that this is a case of metaphoric extension, a case of borrowing some conspicuous property of an object and apply the property to another object possibly outside the sortal range of the same property. Let us consider the predicate 'break'. What sort of things can break? Just concrete objects, of course. But can one not also break a habit/tradition/fast/promise/contract/law? So are we to extend the sortal range beyond the concrete objects? We claim not. We claim that these other cases, as common and pervasive as they are, are just cases of metaphoric extensions although we will not attempt to justify our position here. But not all metaphoric extensions cross the boundaries of the sortal range. Take an example of metaphor from Lappin, 'The poor are the negroes of Europe.' Clearly this example is sortally correct.

4. Sowa's Approach (Introduction to Sowa)

Conceptual graph theory (CG) is a KRL based on a system of logic that can express the propositional contents of sentences in a direct way. CG

owes its directness in representing NL semantics largely to C. S. Peirce (1882) and his existential graph (EG). There is a homomorphic function (PHI) relating the underlying logic for CG to predicate calculus. A conceptual graph (cg) is a finite, connected, bipartite graph, bipartite with concept nodes and relation nodes alternating. Each concept has two fields, concept type and individual marker. Every relation is n-adic where $n >= 1$.

The well-formedness for cg's is defined through a canon, which in turn consists of a type hierarchy, a set of individual markers, a conformity relation and a canonical basis. The canonical graphs or well-formed cg's are the closure of the canonical basis under the canonical formation rules. There are four canonical formation rules; copy, restrict, join, and simplify. Copying and simplification are cosmetic rules not affecting the content of a cg. Join is to combine two or more cg's to build a larger cg. For our purposes, restriction is the key operation. For a concept c in a cg u, type(c) may be replaced by a subtype; if c is generic, i.e., if its referent field is empty, an individual marker may be added to the referent field; both of the suboperations constrained under the conformity relation.

It is important to remember that these formation rules are not inference rules and not meaning-or even truth-preserving. We contend that canonical basis constitutes constraints on the type pairing over relations. If we assume that a canonical basis consists of cg types where for each concept c, type(c) is minimal in the sense that type(c) is the smallest type that includes every possible referent for that concept, restriction really surmounts to instantiation of canonical rules/templates/types of which canonical basis is composed. These rules are listed under the headings of the concept catalogue (appendix B2).

For the exercise presented in this paper, the lexicon, the concept catalogue, the relation set, and the type hierarchy for the concepts and relations are given in the appendices. We have tried to maintain the basic structure provided in Appendices of Sowa (1984). In the concept catalogue, we use the notation that was introduced earlier, namely '⇒' for rules or templates instead of '→'. One could mark certain relations negatively such as 'manner' for 'believe' and 'know'. We feel that such negative marking would be necessary within Sowa's program unless we always list all possible relations for a given predicate. But we introduce a new approach to manner adverbs in the next section and appendix B2 presents that approach. We

consider all locative preposition originated relations as abbreviations for partial cg, for example '(under)' as an abbreviation for '(loc) ⇒ [underneath] ⇐ (link)'.

We will actually translate each of the examples making necessary comments as we go.

Chomsky 1. Colorless green ideas sleep furiously.
[IDEA: {*}]−X→(ATTR)−X→ [GREEN]
[IDEA: {*}]−X→(ATTR)−X→[COLORLESS]
[FURIOUSLY]←X−(MANR) ←X−[SLEEP]−X→(EXPR)−X
→[IDEA: {*}]→...

In parsing the subject NP, we attempt to apply the restriction rule to the canonical graphs for 'GREEN' and 'COLORLESS' and experience a type clash since '[IDEA:{*}]' is not a subtype of '[CONCRETE]'. An actual parser might stop right here, deciding that this sentence is sortally incorrect. We represent the illformedness of the graph by attaching 'X' to the edges.

Even if the subject NP had parsed successfully, the sentence would have been sortally incorrect due to the type clash between '[ANIMATE]', the type required of the experiencer for '[SLEEP]' and '[IDEA:{*}]', the actually provided experiencer. We will refer to the former as 'formal experiencer' and the latter, 'actual experiencer'. There is some sort of type clash between the actual manner adverb and the allowed formal manner adverb. It is not as if state verbs like 'sleep' cannot take any manner adverbs, for we can say 'the baby sleeps so sound/peacefully/quietly/lightly/deeply'. At this point one might like to propose to subcategorize manner adverbs into state manner and action manner. But none of these adverbs are allowed for cognitive state verbs such as 'know', 'think', and 'believe'. Thus on a deeper inspection we find that there are different subcategories of states and actions that allow for different types of description in terms of adverbs. We maintain that a deeper analysis is needed than just claiming that state verbs do not take a manner adverb.

Thomason 1. The color of copper is forgetful.
[[COLOR: lambda] ←(ATTR)←[COPPER]: #123]←X−(EXPR)←X
−[FORGET]

The uniqueness of the referent is represented in the cg by the unique identifier '#123'. Read the notation '...[X: lambda] ...' as 'lambda x. ...[X: x]....'. Relative clauses are often translated into lambda expressions. A lambda expression may be viewed a complex type specifier. The complex type whose head concept node is '[COLOR: lambda]' clashes with the formal experiencer '[ANIMAL]'.

Thomason 2. Virginia is left-handed.
[LEFT-HANDED]−X→(ATTR)−X→[STATE: virginia]

Thomason 3. The velocity of light is shiny.
[SHINY]−X→(ATTR)−X→[[VELOCITY: lambda]→(ATTR)→
[LIGHT]: #]

Thomason 4. The discovery of America is an orange.
[ORANGE]−X→(ELEM)−X→[[DISCOVER: lambda]→(obj)→
[COUNTRY: America]: #345]

Thomason 5. The painted desert is in Arizona.
[[DESERT: lambda]←(OBJ)←[PAINT]: #345]
→(LOC)→[INSIDE]←(PART)←[ARIZONA]

Thomason 6. The painted desert is reluctant.
[[DESERT: lambda]←(OBJ)←[PAINT]: #345]
−X→(CHAR)−X→[RELUCTANT]

Notice that in the examples above the painted desert refers to some desert that someone painted in a specific painting event, not the painting itself.

Waldo 1. The taste of lemon is breakable.
[[TASTE: lambda]→(ATTR)→[LEMON]: #245]
−X→(ATTR)−X→[BREAKABLE]

Bergmann 1. The theory of relativity is blue.
[BLUE]←(ATTR)←[[THEORY: lambda]←(OF)←[RELATIVITY]: #346]

Bergmann 2. The theory of relativity is interested in classical music.
[[THEORY: lambda]←(OF)←[RELATIVITY]: #346]←X−(EXPR)←
X−[INTERESTED]−X→(OBJ)−X→[CLASSICAL MUSIC]

We propose to call a predicate such as '[INTERESTED]' an unstable predicate. These predicates are unstable in the sense that the type of things that

can interest is constrained by the type of experiencer. The type of things lower animals can be interested in is severely more restricted than the type of things humans can be interested in. There appears to be a general type, perhaps 'ANIMAL' that can have an interest regardless of the type of the object, but within that general type different subtypes are mapped with different types of objects.

Lappin 1. Quadruplicity drinks procrastination.
[QUADRUPLICITY]←X−(AGNT)←X−[DRINK]−X→(OBJ)−X→
[PROCRASTINATION]

Lappin 2. This stone thinks of Vienna.
[STONE: #this] ←X−(AGNT)←X−[THINK]→(OBJ)→[PROP:
Vienna]

Predicates are known to have proposition arguments involving some individual objects whose contents are left unspecified. Thus, Cullingford (1986) translates the sentence 'Olivia sent Muhammed to Hartford' into the Conceptual Dependency Graph as below:

(cause con 1 (episode actor (person persname (Olivia)))
con 2 (ptrans actor HUMO obj HUMO to (prox part POLO)))

Here HUMO is a pointer to the concept representing Muhammed and POLO, the city Hartford. Roughly this represents that an unspecified episode involving Olivia caused Muhammed's transporting himself to Hartford. We propose to represent such an unspecified proposition involving an individual X as '[PROP: X]'. So semantically we are thinking of a particular proposition involving X, if not fully specified.

Lappin 3. Prime numbers are hungry.
[HUNGRY]−X→(EXPR)−X→[PRIME NUMBER]

Lappin 4. Love has a smooth surface.
[SMOOTH]←(CHAR)←[SURFACE]←X−(PART)←X−[LOVE]

Lappin 5. My table is recursively enumerable.
[RECURSIVELY ENUMERABLE]←X−(CHAR)←X−[TABLE]←
(OBJ)←[OWN]→(STAT)→[PERSON: # I]

Lappin 6. Bill knows the theory slowly.
[KNOW] −

(AGNT)→[PERSON: #bill]
(OBJ)→[THEORY: #267]
(MANR)−X→[SLOW]

While one cannot know things slowly, people know things clearly, thoroughly, unambiguously, etc. We reanalyze so-called manner adverbs in the following section.

Lappin 7. The man intentionally believed the claim.
[BELIEVE] −
(EXPR]→[MAN: #167]
(OBJ)→[CLAIM: #264]
(MANR)−X→[INTENTIONALLY]
Here too one can believe things firmly, implicitly, unshakably, etc.

Lappin 8. Bill thought under the problem.
[THINK] −
(EXPR)→[MAN: #bill]
(LOC)→[UNDERNEATH]←X−(LINK)←X−[PROBLEM: #275]

We use '(LINK)' as some unspecified linkage. We defer the analysis of prepositions for another paper.

Lappin 9. Sam sat beside the sky.
[SIT] −
(AGNT)→[MAN: #sam]
(LOC)→[PROXIMITY]←X−(LINK)←X−[SKY: #363]

The sortal incorrectness here arises due to the type clash between '[CLOSED-ENDED]' and '[SKY]' which is not closed-ended.

Lappin 10. John wrote on top of the theory.
[WRITE] −
(AGNT)→[MAN: #john]
(LOG)→[TOP]←X−(LINK)←X−[THEORY: #298]

Lappin 11. OK. Bees are highly excitable.
?. Amoeba are highly excitable.
??. Yogurt backteria are highly excitable.
???. Certain plants are highly excitable.

*. My table is highly excitable.
**. Real numbers are highly excitable.

[HIGHLY EXCITABLE]→(EXPR)→[BEE: {*}]
[HIGHLY EXCITABLE]−X→(EXPR)−X→[TABLE]←(OBJ)←
[OWN]→(STAT)→[PERSON: #I]

Other examples in this group illustrate degrees of metaphoric extensibility. The closer the types are, the clearer the similarity in behavior denoted, the easier the metaphoric extension.

5. Proposed Modifications to Sowa's CG

Some of the examples discussed above raise some interesting issues. Thomason 6 involves volition, which certainly is peculiar to animals. Thomason 1, Bergmann 2, Lappin 2, Lappin 6, and Lappin 7 involve cognition, a human-peculiar property. We might capture this generalization by having a still higher-level rule to the effect that [COGNITIVE PROCESS] ⇒ (EXPR) ⇒ [HUMAN]. Then one need not specify the formal experiencer for individual cognitive predicates. Thus the canonical basis seems to be hierarchically structured, rather than just a list of basic graphs. Unstable predicates illustrated in connection with Bergmann 2 also supports the hierarchical organization of canonical basis. The range of potential human interest should be somehow captured on a more general level than individual predicate level.

Chomsky 1, Lappin 6, and Lappin 7 illustrate sortal incorrectness involving so-called manner adverbs. The notion 'manner adverb' is notoriously obscure. As we mentioned in connection with Chomsky 1, different so-called state and action verbs can co-occur with different types of adverbs. While one may not know something slowly/fast/furiously/peacefully, one knows things clearly/vaguely/thoroughly. We propose to represent sortal restriction involving so-called manner adverbs or more inclusively all adverbs as a restriction on adverbs as predicates. So Chomsky 1, Lappin 6, and Lappin 7 will be reanalyzed as below. We list both Sowa's and the proposed analyses together for convenience here.

Chomsky 1. Colorless green ideas sleep furiously.

Sowa: [FURIOUSLY] ←X−(MANR)←X−[SLEEP]−X→(EXPR)−X→
[IDEA: {*}]→ ...

Oh & Seo: [FURIOUS]−X→(OBJ)−X→[SLEEP]−X→(EXPR)−X→

[IDEA: {*}]→ ...

Lappin 6. Bill knows the theory slowly.

Sowa : [KNOW] –
(AGNT)→[PERSON: #bill]
(OBJ)→[THEORY: #267]
(MANR)–X→[SLOW]

Oh & Seo : [KNOW] –
(AGNT)→[PERSON: #bill]
(OBJ)→[THEORY: #267]
(OBJ)←X–[SLOW]

Lappin 7. The man intentionally believed the claim.

Sowa : [BELIEVE] –
(EXPR)→[MAN: #167]
(OBJ)→[CLAIM: #264]
(MANR)–X→[INTENTIONALLY]

Oh & Seo : [BELIEVE] –
(EXPR)→[MAN: #167]
(OBJ)→[CLAIM: #264]
(OBJ)←X–[INTENTIONAL]

6. Conclusion

Some example sentences of sortal incorrectness have been analyzed within an extended conceptual graph theory. The conceptual structures for the concepts presented in appendix B2 constitutes the canonical basis. Formation rules are wellformedness rules in the conceptual graph theory and these rules keep sortally incorrect conceptual graphs from being added to the knowledge base. Some fundamental modifications have been proposed to Sowa's theory. To capture some important generalizations, we proposed to hierarchically structure canonical basis. We also presented a new approach to manner adverbs.

We feel that one of the most urgent research topics related to the study of sortal incorrectness is the ontological structure. It appears that we need not one version of ontology but several, quite possibly infinitely many. The same object may be viewed as an instance of one type for one purpose and as an instance of another type for another purpose. The problem of structuring canonical basis is related to, if not a special case of, the problem of structuring the ontology.

APPENDIX A: SORTALLY INCORRECT SENTENCES BY AUTHORS

Chomsky:

1. Colorless green ideas sleep furiously.

Thomason:

1. The color of copper is forgetful.
2. Virginia is left-handed.
3. The velocity of light is shiny.
4. The discovery of America is an orange.
5. The painted desert is in Arizona.
6. The painted desert is reluctant.

Waldo:

1. The taste of lemon is breakable.

Bergmann:

1. The theory of relativity is blue.
2. The theory of relativity is interested in classical music.

Lappin:

1. Quadruplicity drinks procrastination.
2. This stone thinks of Vienna.
3. Prime numbers are hungry.
4. Love has a smooth surface.
5. My table is recursively enumerable.
6. Bill knows the theory slowly.
7. The man intentionally believed the claim.
8. Bill thought under the problem.
9. Sam sat beside the sky.
10. John wrote on top of the theory.
11. OK. Bees are highly excitable.
    ?. Amoeba are highly excitable.
    ??. Yogurt backteria are highly excitable.
    ???. Certain plants are highly excitable.
    *. My table is highly excitable.
    **. Real numbers are highly excitable.

APPENDIX B1: LEXICON

a indefinite article; no concept

amoeba count noun; **AMOEBA**

an indefinite article; no concept
and conjunction; /////////
are 3rd person plural of *be*; no concept
Arizona proper name; [STATE: Arizona]
bee count noun; BEE
believe transitive verb; BELIEVE
beside preposition; no concept
Bill proper name; [HUMAN: Bill]
blue adjective; BLUE
breakable adjective; BREAKABLE
certain adjective; CERTAIN
claim transitive verb; CLAIM
classical music count noun; CLASSICAL MUSIC
color count noun; COLOR
colorless adjective; COLORLESS
commically adverb; COMMICALLY
copper mass noun; COPPER
discovery of America count noun; DISCOVERY OF AMERICA
door count noun; DOOR
drink transitive verb; DRINK
excitable adjective; EXCITABLE
forgetful adjective; FORGETFUL
furiously adverb; FURIOUSLY
green adjective; GREEN
hammer count noun; HAMMER
has 3rd person singular present of have; no concept
highly adverb; HIGHLY
hungry adjective; HUNGRY
idea count noun; IDEA
in preposition; no concept
intentionally adverb; INTENTIONALLY
interested in adjective; INTERESTED IN
is 3rd person singular present of be; no concept
John proper name; [HUMAN: John]
know transitive verb; KNOW
left-handed adjective; LEFT-HANDED

lemon count noun; LEMON
love transitive verb; LOVE
man count noun; MAN
my pronoun, possessive case, indexical term; ?
of preposition; no concept
ok interjective; no concept
on top of preposition; no concept
open transitive verb; OPEN
orange count noun; ORANGE
painted desert count noun; PAINTED DESERT
plant transitive verb; PLANT
prime number count noun; PRIME NUMBER
problem count noun; PROBLEM
procrastination abstract noun; PROCRASTINATION
quadruplicity abstract noun; QUADRUPLICITY
real number count noun; REAL NUMBER
recursively enumerable adjective; RECURSIVELY ENUMERABLE
reluctant adjective; RELUCTANT
Sam proper name; [HUMAN: Sam]
sat intransitive verb; SIT
shiny adjective; SHINY
sky count noun; SKY
sleep intransitive verb; SLEEP
slowly adverb; SLOWLY
smile intransitive verb; SMILE
smooth adjective; SMOOTH
stone mass noun; STONE
surface count noun; SURFACE
table count noun; TABLE
taste count noun; TASTE
the definite article; no concept
theory count noun; THEORY
theory of relativity count noun; THEORY OF RELATIVITY
think of transitive verb; THINK OF
this indexical pronoun; ENTITY
thought count noun; THOUGHT

under preposition; no concept
velocity of light count noun; **VELOCITY OF LIGHT**
Vienna proper name; **[CITY: Vienna]**
Virginia proper name; **[HUMAN: Virginia].**
proper name; **[STATE: Virginia]**
with preposition; no concept
wrote transitive verb, past tense; **WRITE**
yogurt bacteria count noun; **YOGURT BACTERIA**

APPENDIX B2: CONCEPT CATALOGUE
ANIMATE
BELIEVE
[BELIEVE – <<<<The man *intentionally believed* the claim>>>>
(EXPR) ⇒ [ANIMATE]
(STAT) ⇒ [PROP]
BIPED
BLUE
[BLUE] – <<<<*The theory of relativity* is *blue*>>>>
(ATTR) ⇐ [CONCRETE] AS AN INSTANCE OF A SCHEMA
BREAKABLE
[BREAKABLE] – <<<<*The taste of lemon* is *breakable*>>>>
(ATTR) ⇐ [SOLID]
CLOSED/LOWENDED, CONCRETE
COLOR
COLORLESS
[COLORLESS] ⇐ (ATTR) ⇐ [CONCRETE]
CONCRETE
COUNTABLE
[COUNTABLE] – <<<<*California* is *countable*>>>>
(ATTR) ⇐ [ENTITY GROUP]
CUP
DRINK<ACTION
[DRINK] – <<<<*Quadruplicity* drinks *procrastination*>>>>
(AGNT) ⇒ [ANIMATE]
(OBJ) ⇒ [LIQUID]
(INST) ⇒ [CUP] ⇒ (ATTACHED) ⇒ [STRAW] STRUC-

TURED
ENTITY GROUP
FORGET
[FORGET] –
(EXPR) ⇒ [ANIMAL]
(OBJ) ⇒ [PROP]
FURIOUSLY<ACTION MANNER
GREEN
[GREEN] ⇐ (ATTR) ⇐ [CONCRETE]
[HIGHLY EXCITABLE]
[HIGHLY EXCITABLE] ⇒ (EXPR) ⇒ [ANIMAL]
HUMAN
HUNGRY
[HUNGRY] – <<<<*Prime numbers* are *hungry*>>>>
(EXPR)⇒[ANIMAL]
INANIMATE
INTENTIONAL
[INTENTIONAL] ⇒ (OBJ) ⇒ [VOLITIONAL ACT]
INTERESTED
[INTERESTED] – <<<<*The theory of relativity* is *interested in classical music*>>>>
(EXPR) ⇒ [ ]
(OBJ) ⇒ [ ]AN unstable predicate in that the allowed type only HUMANs in the abstract, etc.
KNOW
[KNOW] – <<<<Bill *knows* the theory *slowly*>>>>
(EXPR) ⇒ [ANIMATE]
(STAT) ⇒ [PROP]
LEFT–HANDED
[LEFT–HANDED]– <<<<Virginia is left–handed>>>>
(ATTR) ⇐ [BIPED]
LIQUID
ON SURFACE
ORANGE
[ORANGE] – <<<<The discovery of America is an orange>>>>
(ELEM) ⇐ [ORANGE]

PROP

PROXIMITY

[PROXIMITY] ⇐ (LINK) ⇐ [CLOSED-ENDED]

RECURSIVELY INUMERABLE

[RECURSIVELY INUMERABLE]-<<<<My table is recursively enumerable>>>>

(ATTR) ⇐ [SET]

RELUCTANT

[RELUCTANT]-<<<<The painted desert is reluctant>>>>

(CHRC) ⇐ [HUMAN{SELF-WILLED}] property in {} a defining one

SET

SHINY

[SHINY] - <<<<The velocity of light is shiny>>>>

(ATTR) ⇐ [CONCRETE]

SLEEP

[SLEEP] - <<<<Sam sleeps quickly>>>>

(EXPR) ⇒ [ANIMATE]

SLOW

[SLOW]

(OBJ) ⇒ [MOTION]

SMOOTH

[SMOOTH] - <<<<Love has a smooth surface>>>>

(CHRC) ⇐ [SURFACE]⇐(PART) ⇐ [CONCRETE]

SOLID

STRAW

SURFACE

[SURFACE] ⇐ [CONCRETE]

THINK

[THINK] - <<<<Bill thought under the problem>>>>

(AGNT) ⇒ [HUMAN]

(OBJ) ⇒ [PROP]

(LOC) ⇒ [UNDERNEATH] ⇐ (LINK) ⇐

TOP

[TOP] ⇐ (LINK) ⇐ [CONCRETE]

UNDERNEATH

[UNDERNEATH] ⇐ (LINK) ⇐ [CONCRETE]

WRITE

[WRITE] – <<<<John wrote on the top of the theory>>>>

(AGNT) ⇒ [HUMAN]

(OBJ)

(INST)

(LOC) ⇒ [ON SURFACE] ⇐ (PART) ⇐ [INANIMATE]

{(ON TOP OF) ⇒ [HARD-SURFACE]} wirte on hand???

APPENDIX B3: RELATIONS

agent	(AGNT)	
attached	(ATTACHED)	
attribute	(ATTR)	
characteristic	(CHRC)	
element	(ELEM)	
experiencer	(EXPR)	
instrument	(INST)	
link	(LINK)	
location	(LOC)	
manner	(MANR)	
object	(OBJ)	
on top of	(ON TOP OF)	defined
part	(PART)	
status	(STAT)	
under	(UNDER)	defined

References

Bergmann, M. (1977) 'Logic and Sortal Incorrectness,' *The Review of Metaphysics* vol. xxxi, 61–79.

Cook, Walter (1989) *Case Grammar Theory*, Georgetown University Press.

Cullingford, Richard (1986) *Natural Language Processing*, Rowman & Littlefield.

Davis, Ernest (1990) *Representations of Commonsense Knowledge*, Morgan Kaufmann Publishers, Inc., San Mateo, California.

Dixon, R. (1991) *A New Approach to English Grammar, On Semantic Princi-*

ples, Clarendon Press.

Freeze. R. (1992) 'Existentials and Other Locatives,' *Language* 68, 553–595.

Keil, Frank C. (1989) *Concepts, Kinds, and Cognitive Development*, The MIT Press.

Lappin, Shalom (1981) *Sorts, Ontology, and Metaphor*, Walter de Gruyter.

Martin, R. L. (1974) 'Sortal Ranges for Complex Predicates,' *Journal of Philosophical Logic* 3: 159–167.

Peirce. C. S. (1878) 'How to Make Our Ideas Clear,' *Popular Science Monthly* 12, 286–302. Reprinted in *Writings of Chales* S. Peirce, Vol. 3, Indiana University Press, Bloomington: 257–276.

Sowa, John (1984) *Conceptual Structures*, Addison–Wesley.

Sowa, John (1991) (Ed) *Principles of Semantic Networks*, Morgan Kaufmann.

Thomason, Richmond (1972) 'A Semantic Theory of Sortal Incorrectness,' *Journal of Philosophical Logic* 1: 209–258.

Velardi, P., Pazienza, M. T., and DeGiovanetti, M. (1988) 'Conceptual Graphs for the Analysis and Generation of Sentences,' *IBM Journal of Research and Development* 32(2): 251–267.

Professor Jonathan C. Oh
Computer Science Telecommunications
4747 Troost Avenue
The University of Missouri–Kansas City
Kansas City, Missouri 64110–2499
U. S. A.

Professor Sang-Ok Seo
Department of English
Chungnam National University
Taejon, 305–764
Korea