KNOWLEDGE REPRESENTATION OF AN ENCYCLOPEDIA ARTICLE
SNeRG Technical Note 28

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Abstract

This paper documents the attempt to produce a reasonable knowledge representation of a brief encyclopedia article about a commonly known subject. A three stage process was used to produce the knowledge representation: analysis of the meaning of the English language text; representation of the knowledge represented by the text in standard first order logic; and an idiomatic translation from the first order logic representation into the SNePSUL (SNePS user language). This analysis was undertaken for each sentence, treating each as an independent text to the greatest extent practically possible. Despite the brevity and relative simplicity of the article represented, a number of interesting problems were encountered, and are discussed in the paper.

1 Introduction.

The purpose of this project is to provide a representation of the knowledge contained in a brief article found in a common encyclopedia. Specifically, this project is an attempt to represent the knowledge contained in the article about carrots found in the *World Book Encyclopedia.* The applicable text of the article follows (World Book, 1991:249):

> **Carrot** is a plant with an orange root that is eaten as a vegetable. Carrots contain vitamin B_1 and small amounts of vitamins B_2 and C. A substance called *carotene* also comes from carrots. Carotene is used by the human body to produce vitamin A. In addition, carrots are rich in sugar and contain much iron.
>
> People eat carrots alone or in salads. They also eat boiled carrots. In some parts of the world, carrots have been roasted, ground, and used as a substitute for coffee. The plant's thick, lacy leaves and long stems are sometimes chopped up and sprinkled on meats to improve flavor.
>
> Carrots are grown from tiny seeds planted from $1\frac{1}{2}$ to 2 feet (46 to 61 centimeters) apart. They grow best in deep, rich soils that contain sand or muck. Carrots can survive cool winters and can withstand much summer heat. Gardeners in the northern part of the United States often raise summer and fall crops of carrots. Each crop takes about 100 days to grow.
>
> Carrots are native to the Mediterranean region. The ancient Greeks and Romans grew carrots that had thin, tough roots. They used the plants as medicine but not as a food. Carrots resembling modern types were later developed in France and were common in Europe by the 1200's. Common types of carrots planted today include *Imperator, Nantes, Chantenay,* and *Danvers.*

The knowledge-representation language chosen to represent the content of this article is SNePS (Shapiro, et al. 1995; Shapiro, et al. 1992-94).

2 General Remarks.

The *World Book Encyclopedia* is an encyclopedia for which the intended reader is a child in grade school, middle school, or high school (though it is also consulted by post-baccalaureate adults!). It has a fairly clear, relatively simple style of expression, and the content of its articles is seldom difficult or challenging. As should be evident from the article quoted above, the style tends to brief declarative sentences with simple vocabulary. In short, it is intended to be easy to read and understand. When selecting this article for my knowledge-representation project, I was attracted to the commonplace, concrete nature of the subject. Certainly, if one can represent knowledge at all, one should be able to represent some basic knowledge about such a common everyday object as a carrot. Nevertheless, I have found this to be a challenging project. knowledge representation is much harder in practice than it appears from a study of knowledge-representation theory.

I believe that the representations I have chosen are "reasonable" in the sense that a reasonable native speaker of English with the general background knowledge one could reasonably expect of a normal adult of moderate education would agree that *the knowledge represented is within the bounds of what the author of the article intended to communicate to its readers.* Clearly, this statement is rife with qualification and undefined terms, but discussion of these issues would be beyond the scope of this paper. The points I wish to convey are these:

- the author of the article knows certain things about carrots
- the author intends to communicate a subset of that knowledge to the readers by means of the article
- the reader has a responsibility to interpret the article in order to understand this knowledge
- that knowledge which was both intended for communication by the author and successfully reproduced by the readers' interpretations is what we wish to represent.

The actual knowledge representation, to be "reasonable" in the sense above, should not go beyond the bounds of the intended communication. In fact, it probably is a proper subset of the intended communication due to the practical difficulties of constructing the actual representations.

The reason for introducing this notion of a reasonable knowledge representation is to avoid falling prey to two incorrect approaches to the representation task. First is the notion that the knowledge to be represented must be entirely confined to the literal meaning of the text. In such an approach, the phrase *carrots have been roasted, ground and used as a substitute for coffee* would have to be interpreted as three *unrelated* statements about carrots (Carrots have been roasted. Carrots have been ground. Carrots have been used as a substitute for coffee.). This is because in this syntactic pattern, there is no *necessary* relation between the three states. (To convince yourself of this, substitute other grammatically similar words for the originals—for example, *carrots have been pureed, pickled and used as a substitute for yams*—which, to me at least, have no obvious connection, much less a necessary one.) Because a reasonable knowledge representation may draw on the interpretation of the reader, however, we can instead represent this phrase as describing a *sequence of related actions.* That is, the reader may well interpret the intended meaning of this phrase in the following manner: "(some) Carrots have been roasted; subsequently, the roasted carrots have been ground, and the resulting ground roasted carrot material has been used as a substitute for coffee." Given what the hypothetical reader can be expected to know about coffee, this second interpretation seems to me to be entirely reasonable.

The question is whether this interpretation captures the knowledge that the author intended to convey. Clearly, the proposition that carrots have been roasted is true, as is the proposition that carrots have been used as a substitute for coffee. These are clearly implied by the text. Whether the carrots were roasted *in order to be* used as coffee, however, is not clearly implied. If this were true, however, it would explain why the author mentioned that the carrots had been roasted in the first place. Simply to say that "carrots have been roasted" is in some sense not very interesting. That is, I believe it would not be very interesting to the hypothetical reasonable reader. It is true, but does not seem to stand alone very well—I think that the reasonable reader would ask *Why?* if this statement were left in isolation. Somehow the structure of the narrative suggests that this statement is part of a larger description. To avoid representing this *implicitly* conveyed knowledge because it is not obviously or necessarily present in the literal meaning of the text is not reasonable. A reasonable knowledge representation must represent implicit knowledge as well as literal information.

The second incorrect approach is to go too far into the representation of implicit knowledge, in effect, to represent what is not reasonably supported by the text. For example, in the statement that the ancient Greeks and Romans *used the plants as a medicine but not for food*, we might plausibly assume that the author of the article (presumably an expert on carrots) knew what ailments carrots were prescribed for, and possibly even if carrots are still used as medicine in modern times. Clearly, however, this knowledge is not conveyed by the text of the article, and an attempt to incorporate it into the knowledge representation of the article would be foolish. The statement that carrots *were common in Europe by the 1200's* must similarly be left as it stands without trying to incorporate knowledge unsupported by the text of the article. There may well be some readers who know the precise year that carrots became common in Europe, or that knowledge may be available from standard carrot reference literature, but a representation of the knowledge *in the article* must be confined to at most the knowledge the author intended to convey to the reader. To incorporate more than this into the representation of the knowledge in the article would be unreasonable, even if the additional knowledge is completely true.

We see then that a "reasonable" knowledge representation must incorporate reader inferences of implicitly conveyed knowledge but must not err by over-reaching the knowledge supported by the text. How can these conflicting constraints be satisfied? This is the common problem between literal meaning and interpretation that any translation process must confront. Unfortunately, finding the correct balance between what the author has literally expressed and the meaning that the author intended to convey seems to be a matter of judgment on the part of the human being doing the knowledge representation. In a sense, that person is a "knowledge engineer" and is subject to the same issues of all engineering efforts. That is, for all but the simplest cases, decisions must be made that depend as much on the judgment of the individual engineer as on any objective tests or procedures. At this point, the state of the art in artificial intelligence research does not provide an algorithm for such judgments. Knowledge representation is an art form and not (yet) a science.

3 Methodology and General Problems.

The knowledge-representation language chosen for this project is SNePS (Shapiro et al. 1995; Shapiro et al. 1992-94), a semantic-network language. There is some dispute about what SNePS provides that is not already present in standard first-order logic; SNePS can simulate certain higher-order logic statements (such as quantification of predicates over predicates), but at minimum SNePS provides the full expressive power of standard first-order logic. Therefore, my approach has been as follows:

- first express the knowledge in standard first-order logic
- then convert these into a SNePS representation
- finally try to take advantage of SNePS idiosyncrasies (such as the non-standard connectives) to simplify the representation, if possible.

In my first efforts, I tried to "think in SNePS" and reason by drawing SNePS semantic-network diagrams. While this exercise was instructive, it was not terribly productive. I learned that I became easily confused when trying to understand the semantic interpretation of some of the networks I had drawn, particularly if the networks were graphically complicated. By going through the first step of a first-order logic representation, I hope that I have managed to avoid this confusion.

3.1 Problems with Logical Quantifiers.

The most significant drawback to working in standard first-order logic, expressed either in logic notation or as SNePS networks, is the restricted nature of the quantifiers. In first-order logic, we can only make statements about *all* the members of a certain class (∀ quantification) or about whether the set that represents the class is non-empty (∃ quantification). This is disturbing when trying to discuss statements that are *generally* true or that are true of *typical* members of the class. For example, we can say that "*all* carrots have an orange root" with a fair degree of confidence. However, it is not correct to say that "for *all* carrots, it is true that people eat them," even though we are told explicitly that "people eat carrots." Horses also eat carrots, and therefore those carrots eaten by horses cannot also be eaten by people. This means that strictly there are at minimum two distinct sets of carrots, disjoint subsets of the set of all carrots, which are also subsets of the set of carrots that are eaten, but only one of which consists of carrots that are eaten by people. This seems to be a true expression of the idea behind the statement that "people eat carrots" but it is rather complicated and confusing. Does our knowledge representation for "people eat carrots" truly need to be so elaborate?

In the strict sense of the quantifiers used in standard first-order logic, I believe that it does. Even if the reader knows nothing of horses, it should still be clear that those carrots that are eaten are not the same as those carrots that are used as a substitute for coffee; a reasonable knowledge representation must somehow express this difference without excessively obscuring the common nature of the two. In standard first-order logic we really have no way of representing such quantitative but not easily quantifiable notions as "usually" or "typically" or of default or expected values. Even as simple an idea as "some" presents difficulties. The notion of "some" is usually expressed in standard first-order logic with the existence quantifier ∃, but this is really not a correct representation for the meaning of the English word "some". The existence quantifier applied to a sentence means that the sentence is true if any *single* individual in the universe of discourse satisfies the sentence, but the idea expressed by the English word "some" is very often to be interpreted as "a significantly large subset or quantity, but not the whole set or quantity" and does not refer to "some single individual." Here again, a strict application of first-order logic quantifiers would force us to introduce a subset (which could be a singleton, but not empty) to express the notion of this English sense of "some." Unfortunately there is no straightforward way to represent the notion that this subset is a "significantly large" part of its superset.

3.2 Trying to Represent the "Typical".

In spite of these difficulties, first-order logic offers many advantages as a knowledge-representation scheme. Its notation is relatively simple and unambiguous (for the experienced reader) and can be given a clear semantic interpretation. Standard first-order logic sentences are easily translated into SNePS in a natural manner. The expressive power of standard first-order logic is considerable, even if not completely sufficient for the purposes of this project. If one "abuse" can be tolerated, then first-order logic (as abused) will serve as a very useful foundation for the actual SNePS representation. The abuse I wish to introduce is the idea of a class of *typical carrots*. This is not a well-defined class. There is no set that I can exactly specify that corresponds to the "typical carrots". I introduce this notion to avoid the problem of making statements about "all carrots" that clearly do not apply to *all* carrots literally. This abuse introduces its own problems (mainly in the fact that this class cannot be well defined) but also seems to reflect an actual *intensional entity* that underlies much of the knowledge in the article. The statements in the article are not made so much about identifiable, differentiable individual carrots with real existence in the physical world as about intensional individuals, *typical* carrots. The knowledge that we want to represent is also about these typical carrots.

How is the "typical carrots" class to be used? Consider as an example the first sentence: *Carrot is a plant with an orange root that is eaten as a vegetable.* While this is a single sentence in English, it actually conveys knowledge about two different kinds of carrot. The first is the statement that *carrot is a plant with an orange root.* This is true of all physical carrots in the world throughout time (at least as far as we can tell from the sentence). But the part of the sentence that says *carrot ... is eaten as a vegetable* is presumably true of *typical* carrots, but need not be true of all physical carrots whatsoever. *Real* carrots are indeed plants with orange roots—*typical* carrots are eaten as vegetables. I have chosen to represent this distinction by separate logical sentences saying, in the first case, that if an individual x is a (real) carrot then it is a plant and it has an orange root, and, in the second, that if an individual x is a typical carrot, then it is eaten as a vegetable. It seems important to me to be able to distinguish these two categories of carrots. We should be able to learn from the article that *all* carrots are plants whether they are eaten as vegetables or used as a substitute for coffee. We should also be able to learn that *typically* a carrot is eaten as a vegetable. The representation of the knowledge conveyed by the article must support this distinction.

3.3 Problems Representing Inherited Properties.

This idea of a distinction between the class of real carrots and that of typical carrots is not one that I am entirely happy with. It is clear to me that some way to distinguish between knowledge that applies to all carrots and knowledge that applies to typical carrots must be present somehow. By making separate classes, however, we introduce the problem of inherited qualities. To what extent is a "typical carrot" a carrot? If we think of classes as representing sets of individuals, then clearly there is not a subclass–superclass relation between these two classes. That is, the class of "carrots" is intended to represent the set of physically real individual carrots in the world, while the class of "typical carrots" is intended to represent a set of *intensional* entities, carrots-as-objects-of-thought one might say. Between sets representing real versus intensional entities there cannot be a subset–superset relationship. It is also not satisfying to think of the class of typical carrots as a modification of the class of real carrots, because of this mismatch between real and intensional class members. There must be some relationship between the two classes, however, or it is meaningless to make the initial distinction. Clearly real carrots and typical carrots are, in some sense, both carrots. Clearly, we want an individual x that is a member of the class of typical carrots to *inherit* the fundamental properties of all carrots, such as being a plant and having an orange root. How can we achieve this without obscuring the distinction between the actual and the typical?

I have not come up with a particularly good solution to this problem. The best solution I have at this point is to fall back on a variation of the much-maligned "is a" relationship. In this case, if x "is a" typical carrot, then x "is a" carrot. In terms of the SNePS representation, since *all* individuals are held to be intensional, then the members of the class representing "real" carrots are just as much intensional individuals (objects of thought) as those members of the class representing "typical" carrots. For this reason, I have chosen the class–member SNePS case frame to represent this "is a" relationship. In my representation, a member of the class representing typical carrots is a member of the class representing real carrots. While this weakens the distinction between the two classes, I still maintain that some distinction between the two classes is necessary. This distinction is represented by the lack of an explicit subclass–superclass relationship. The two classes are related at the level of individual members, but at no higher level. I am well aware of the problems with this approach, but I think that it does make it possible to preserve the facts that there are actual carrots, there are typical carrots as objects of thought, and both typical carrots and actual carrots are both (when considered as individuals) "carrots". Better schemes for addressing these issues are to be welcomed. These problems remain open, in my opinion.

4 Knowledge Representation of the Article.

This section contains the actual knowledge representation of the article. Each sentence of the article is the subject of a separate subsection. Each subsection is structured in the following manner:

1. the subsection title (which is the number of the sentence)
2. the text of the sentence in boldface print
3. an informal discussion and/or paraphrase of the knowledge represented by the English sentence

4. a first-order logic representation of the knowledge, with appropriate syntax and semantics
5. the SNePS interpretation of this first-order logic representation, with appropriate syntax and semantics

Some sentences will also be accompanied by a graphic representation of the SNePS semantic network. (While it may be marginally more instructive to see all SNePS representations in graphic form, this would significantly increase the length of this paper.) The "denotation operator" is represented by double-line square brackets, ⟦ ⟧. That is, "⟦x⟧" is a meaning function from the form inside the bracket to its meaning and would be followed by a description of the thing that x denotes. For example, the word "snow" is a syntactic symbol. ⟦`snow`⟧ is the *meaning* of the symbol "snow". Assuming that the language from which we have drawn the symbol "snow" is English then ⟦`snow`⟧ is snow. Once a syntactic symbol has been introduced in either the first-order logic or the SNePS representations, it remains in effect with the same semantic denotation throughout the rest of the paper.

4.1 Sentence 1.

Carrot is a plant with an orange root that is eaten as a vegetable.

4.1.1 Informal Discussion and/or Paraphrase.

This is an example of the distinction between knowledge about actual, physical carrots and intensional, typical carrots. We can paraphrase this as the following: *There is a class representing all the carrots in the world whatsoever. The members of this class are all plants, and they each have their own root respectively. This root has the property that it is orange. Typically, carrots are eaten. This means that there is also a class representing typical carrots, all of whose members are carrots that have the property of being eaten and that have the role of vegetable.*

4.1.2 First-Order Logic Representation.

⟦`Carrot(x)`⟧ is the proposition that the individual x is a member of the class of actual carrots physically existing in the world.

⟦`Plant(x)`⟧ is the proposition that the individual x is a member of the class of actual plants existing in the world.

⟦`HasPart(x,y)`⟧ is the proposition that the individual x has a part of itself that is the individual y; x is composed in part by y.

⟦`Root(x)`⟧ is the proposition that the individual x is a root.

⟦`HasProperty(x,y)`⟧ is the proposition that the individual x has a property represented by y.

⟦`orange`⟧ is the property of being orange.

⟦`TypicalCarrot(x)`⟧ is the proposition that the individual x is a member of the class of intensional entities representing typical carrots.

⟦`eaten`⟧ is the property of being eaten.

⟦`HasRole(x,y)`⟧ is the proposition that the individual x has a role (in an action) as a y.

FOL representation follows:

∀ x Carrot(x)	⇒	Plant(x)
		∧ HasPart(x, f1(x))
		∧ Root(f1(x))
		∧ HasProperty(f1(x), Color(orange))
∀ y TypicalCarrot(x)	⇒	Carrot(x)
		∧ HasProperty(x,eaten)
		∧ HasRole(x,vegetable)

4.1.3 SNePS Interpretation.

```
(describe (assert forall $x1
  ant (build member *x1
      class Carrot)
  cq (build min 4
    max 4
    arg (build member *x1
       class Plant)
    arg (build rel HasPart
       object1 *x1
       object2 (build a1 *x1
      Skf root-of-x1))
    arg (build member root-of-x1
       class Root)
    arg (build object root-of-x1
       property orange))))

(describe (assert superclass Plant
  subclass Carrot))

(describe (assert forall $x2
  ant (build member *x2
     class TypicalCarrot)
  cq (build min 3
    max 3
    arg (build member *x2
       class Carrot)
    arg (build object *x2
       property eaten)
    arg (build rel HasRole
       object1 *x2
       object2 vegetable))))
```

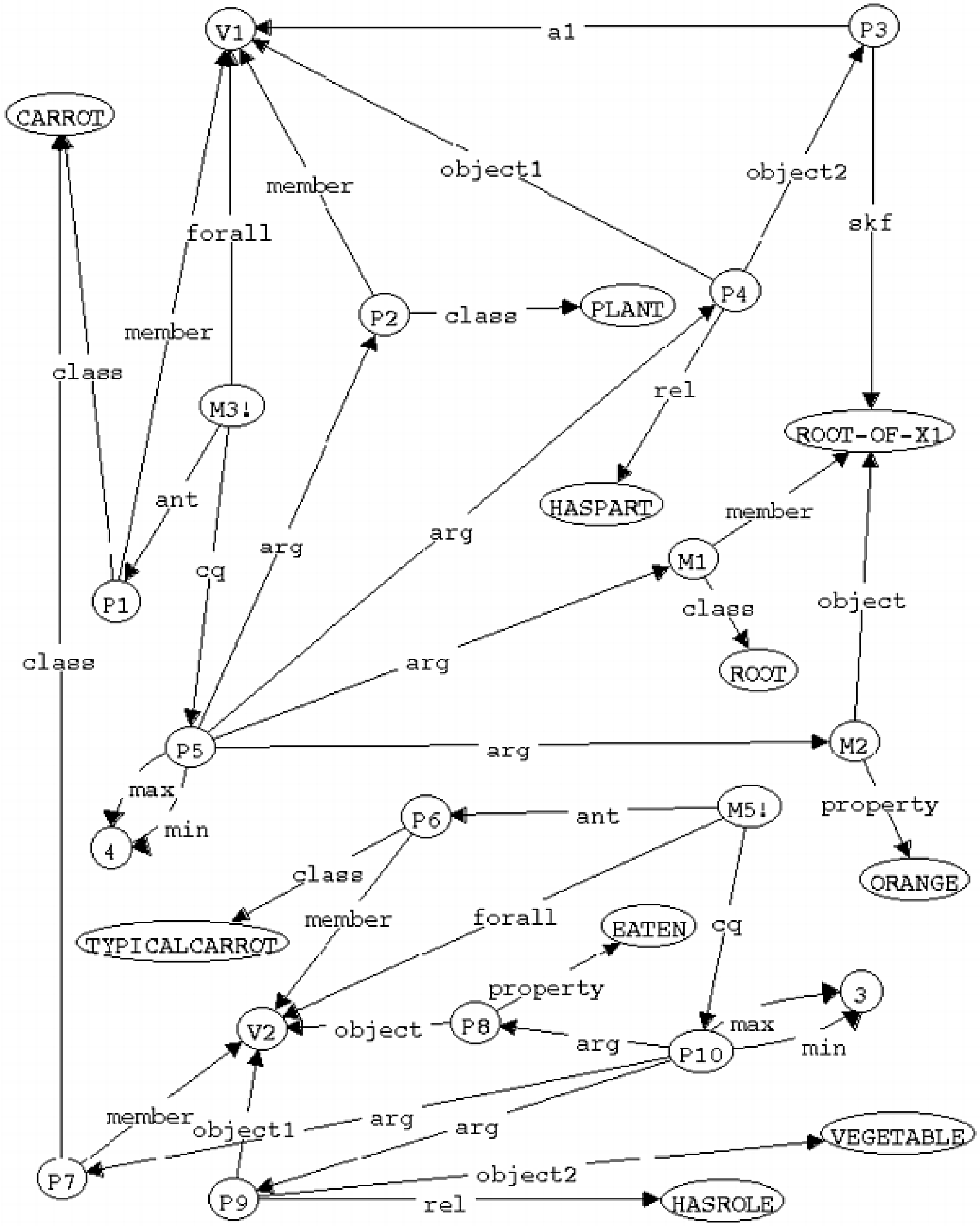

Figure 1: Figure illustrating the sentence *Carrot is a plant with an orange root that is eaten as a vegetable.*

4.2 Sentence 2.

Carrots contain vitamin B_1 and small amounts of vitamins B_2 and C.

4.2.1 Informal Discussion and/or Paraphrase.

This sentence describes things that are true of all carrots, so the Carrot class is the proper one to use. While the sentence does not explicitly introduce the knowledge that there is a class of vitamins that these substances belong to, that seems fairly clear as an implicit piece of knowledge. Since we know that there is an amount involved with two of the vitamins, we know that vitamins must be substances (mass items) rather than discrete units (otherwise we would expect "number" rather than "amount" as the measure word). We can paraphrase as follows: *The members of the class carrot contain three substances in some amount. These substances are all members of the class of vitamins. We do not know how much of the first substance is present, but the second and third substances are present in small amounts. For all three substances, however, each individual carrot has its own proper amounts of the three substances.*

4.2.2 First-Order Logic Representation.

⟦`Contains(x,y)`⟧ is the proposition that the individual x contains y.

⟦`Substance(x,y)`⟧ is the proposition that the individual x is a substance that is identified by y.

⟦`Amount(x,y)`⟧ is the proposition that the amount of substance x has magnitude y.

⟦`Vitamin(x)`⟧ is the proposition that the individual x is a member of the class of vitamins.

⟦`vitamin-B1`⟧ is the vitamin named vitamin B_1.

⟦`vitamin-B2`⟧ is the vitamin named vitamin B_2.

⟦`vitamin-C`⟧ is the vitamin named vitamin C.

FOL representation follows:

$$
\begin{aligned}
\forall \text{ x Carrot(x)} \quad \Rightarrow \quad & \text{Contains(x, f2(x))} \\
& \wedge \text{ Substance(f2(x), vitamin-B1)} \\
& \wedge \text{ Contains(x, g2(x))} \\
& \wedge \text{ Substance(g2(x), vitamin-B2)} \\
& \wedge \text{ Amount(g2(x), small)} \\
& \wedge \text{ Contains(x, h2(x))} \\
& \wedge \text{ Substance(h2(x), vitamin-C)} \\
& \wedge \text{ Amount(h2(x), small)}
\end{aligned}
$$

Vitamin(w)
Vitamin(y)
Vitamin(z)

4.2.3 SNePS Interpretation.

```
(describe (assert forall $x2
  ant (build member *x2
     class Carrot)
  cq (build min 8
    max 8
    arg (build rel Contains
       object1 *x2
       object2 (build a1 *x2
      Skf vitamin-B1-of-x2))
    arg (build rel Substance
       object1 vitamin-B1-of-x2
       object2 vitamin-B1)
    arg (build rel Contains
       object1 *x2
       object2 (build a1 *x2
      Skf vitamin-B2-of-x2))
    arg (build rel Substance
       object1 vitamin-B2-of-x2
       object2 vitamin-B2)
    arg (build rel Amount
       object1 vitamin-B2-of-x2
       object2 small)
    arg (build rel Contains
       object1 *x2
       object2 (build a1 *x2
      Skf vitamin-C-of-x2))
    arg (build rel Substance
       object1 vitamin-C-of-x2
       object2 vitamin-C)
    arg (build rel Amount
       object1 vitamin-C-of-x2
       object2 small))))

(describe (assert forall $w2
  ant (build rel Substance
     object1 *w2
     object2 vitamin-B1)
  cq (build member *w2
    class Vitamin)))

(describe (assert forall $y2
  ant (build rel Substance
     object1 *y2
     object2 vitamin-B2)
  cq (build member *y2
    class Vitamin)))

(describe (assert forall $z2
  ant (build rel Substance
     object1 *z2
     object2 vitamin-C)
```

```
  cq (build member *z2
    class Vitamin)))
```

4.3 Sentence 3.

A substance called *carotene* also comes from carrots.

4.3.1 Informal Discussion and/or Paraphrase.

This sentence is simple, but there is a question about how to best represent the notion expressed in the English phrase "comes from". It seems that this phrase requires some extraction activity to justify it, and I suspect that this is what the author had in mind. However, without more information about this supposed extraction, we really cannot say what was intended. We can say, however, that if carotene "comes from" carrots, it must be contained in carrots, so we paraphrase as follows: *Something called carotene is a member of the class of substances. Carrots contain carotene, each individual carrot containing its own proper carotene.*

4.3.2 First-Order Logic Representation.

⟦`carotene`⟧ is the substance carotene.

FOL representation follows:

$$\forall \text{ x Carrot(x)} \Rightarrow \text{Contains(x, f3(x))} \wedge \text{Substance(f3(x), carotene)}$$

4.3.3 SNePS Interpretation.

```
(describe (assert forall $x3
  ant (build member *x3
     class Carrot)
  cq (build min 2
    max 2
    arg (build rel Contains
       object1 *x3
       object2 (build a1 *x3
      Skf carotene-of-x3))
    arg (build rel Substance
       object1 carotene-of-x3
       object2 carotene))))
```

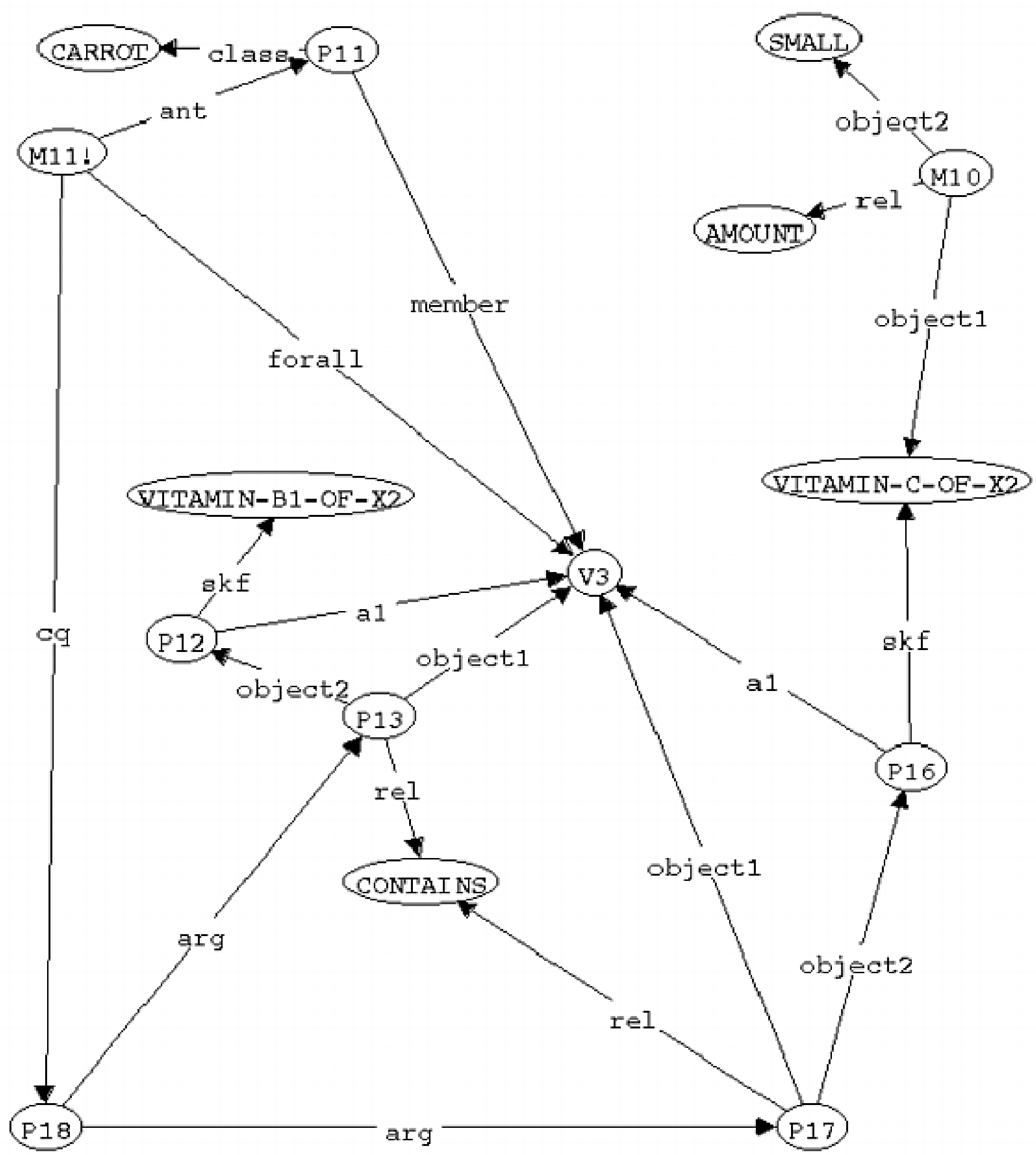

Figure 2: Figure illustrating the sentence fragment *Carrots contain vitamin* B_1 *and small amounts of . . . vitamin C .*

4.4 Sentence 4.

Carotene is used by the human body to produce vitamin A.

4.4.1 Informal Discussion and/or Paraphrase.

I had (and continue to have) some problems with this sentence. The idea of how to represent purpose and goals in first-order logic (or SNePS) is not clear to me yet. The representation so far is not unreasonable, but does not seem optimum. It can be paraphrased as follows: *If the substance carotene is used by the human body, then the human body produces the substance vitamin A. This substance is a member of the class of vitamins. Each individual human body producing vitamin A produces its own proper vitamin A.*

4.4.2 First-Order Logic Representation.

⟦`Human-Body(x)`⟧ is the proposition that the individual x is a member of the class of human bodies (that is, x is a human body).

⟦`Uses(x,y)`⟧ is the proposition that the individual x uses the individual y.

⟦`vitamin-A`⟧ is the vitamin named vitamin A.

FOL representation follows:

$$\forall \text{ x,y Substance(x, carotene)} \wedge \text{Human-Body(y)} \wedge \text{Uses(y, x)} \Rightarrow \text{Produces(y, f4(y))} \wedge \text{Substance(f4(y), vitamin-A)}$$

$$\forall \text{ x Substance(z, vitamin-A)} \Rightarrow \text{Vitamin(z)}$$

4.4.3 SNePS Interpretation.

```
(describe (assert forall $x4
  forall $y4
  &ant (build rel Substance
      object1 *x4
      object2 carotene)
  &ant (build member *y4
      class Human-Body)
  &ant (build rel Uses
      object1 *y4
      object2 *x4)
  cq (build min 2
    max 2
    arg (build rel Produces
       object1 *y4
       object2 (build a1 *y4
      Skf
      produced-vitamin-A))
    arg (build rel Substance
       object1 produced-vitamin-A
       object2 vitamin-A))))

(describe (assert forall $z4
  ant (build rel Substance
```

```
    object1 *z4
    object2 vitamin-A)
  cq (build member *z4
    class Vitamin)))
```

4.5 Sentence 5.

In addition, carrots are rich in sugar and contain much iron.

4.5.1 Informal Discussion and/or Paraphrase.

The "in addition" part of this sentence can be ignored, since this is a cumulative knowledge base. Each fact added to the knowledge base is conjoined with all previously added facts, so all that has to be done here is to represent the knowledge in this sentence alone. This is very similar to sentence 2 above in that the physical carrot contains substances that are roughly quantified. We can paraphrase as follows: *The members of the class carrot contain two (additional) substances. Both substances are present in large amount. For both substances, each individual carrot has its own proper amounts of the two substances.*

4.5.2 First-Order Logic Representation.

$[\![$`sugar`$]\!]$ is the substance sugar.

$[\![$`iron`$]\!]$ is the substance iron.

FOL representation follows:

$$\begin{aligned}\forall \text{ x Carrot(x)} \quad \Rightarrow \quad & \text{Contains(x, f5(x))} \\ & \wedge \text{ Substance(f5(x), sugar)} \\ & \wedge \text{ Amount(f5(x), large)} \\ & \wedge \text{ Contains(x, g5(x))} \\ & \wedge \text{ Substance(g5(x), iron)} \\ & \wedge \text{ Amount(g5(x), large)}\end{aligned}$$

4.5.3 SNePS Interpretation.

```
(describe (assert forall $x2
  ant (build member *x2
     class Carrot)
  cq (build min 8
    max 8
    arg (build rel Contains
       object1 *x2
       object2 (build a1 *x2
      Skf vitamin-B1-of-x2))
    arg (build rel Substance
       object1 vitamin-B1-of-x2
       object2 vitamin-B1)
    arg (build rel Contains
       object1 *x2
       object2 (build a1 *x2
      Skf vitamin-B2-of-x2))
    arg (build rel Substance
```

```
      object1 vitamin-B2-of-x2
      object2 vitamin-B2)
   arg (build rel Amount
      object1 vitamin-B2-of-x2
      object2 small)
   arg (build rel Contains
      object1 *x2
      object2 (build a1 *x2
     Skf vitamin-C-of-x2))
   arg (build rel Substance
      object1 vitamin-C-of-x2
      object2 vitamin-C)
   arg (build rel Amount
      object1 vitamin-C-of-x2
      object2 small))))

(describe (assert forall $w2
  ant (build rel Substance
     object1 *w2
     object2 vitamin-B1)
  cq (build member *w2
    class Vitamin)))

(describe (assert forall $y2
  ant (build rel Substance
     object1 *y2
     object2 vitamin-B2)
  cq (build member *y2
    class Vitamin)))

(describe (assert forall $z2
  ant (build rel Substance
     object1 *z2
     object2 vitamin-C)
  cq (build member *z2
    class Vitamin)))
```

4.6 Sentence 6.

People eat carrots alone or in salads.

4.6.1 Informal Discussion and/or Paraphrase.

This sentence conveys knowledge about another typical situation. People (actually, "typical people") typically eat carrots in one of these manners. Using the same technique as used above, we express a statement about a typical situation by making a statement about typical carrots. In this case we have an either/or situation that could be represented in many possible ways. I have chosen to introduce two new predicates, "eats-with" and "eats-in" to describe the two situations in the sentence. I would prefer to replace these with some more general predicate, but frankly have not been able to think of one that will do the job. For the moment, we will use these.

Each of “eats-with” and “eats-in” is a three-place predicate, with the eater, the eaten carrot and the item eaten with the carrot or in which the carrot is eaten, respectively. Please note that in the first place we are asking for an expression of “eaten alone”. In logic, we can do this with a “not exists” quantifier for the third item of the “eats-with” predicate. Since the version of SNePS I am working with (version 2.3) does not implement the existential quantifier, there is no direct analog to the logic statement. This suggests that we should avoid trying to use the existential quantifier in the first order logic representation. A simple trick to accomplish this is to posit a predicate “Nothing” that denotes that an intensional entity does not exist. With this in hand we can say that “eaten alone” is equivalent to “eats-with nothing”. This is not an ideal solution—the predicate “Nothing” does not behave the same way as a negated existence operator so reasoning with this representation could give surprising results.

The paraphrase of this sentence is then the following: *There is a class of people. Typically, members of the class of people eat carrots in one of two manners, which are mutually exclusive for any typical carrot. Either a person will eat a typical carrot alone (with nothing) or as a part of a salad. In either case, the carrot has the property that it is eaten.*

4.6.2 First-Order Logic Representation.

⟦`Person(x)`⟧ is the proposition that the individual x is a member of the class of persons (people).

⟦`Eats(x, y)`⟧ is the proposition that the individual x eats the object denoted by y.

⟦`Eats-With(x, y, z)`⟧ is the proposition that the individual x eats both the object denoted by y and the object denoted by z (eats y together with z).

⟦`Eats-In(x, y, z)`⟧ is the compound proposition that the individual x eats both the object denoted by y and the object denoted by z and that the object denoted by y is a component part of the object denoted by z.

⟦`Nothing(x)`⟧ is the proposition that the intensional individual x does not exist.

⟦`Salad(x)`⟧ is the proposition that the individual x is a salad.

FOL representation follows:

$$\begin{array}{lll} \forall \text{ x,y Person(x)} \wedge \text{TypicalCarrot(y)} & & \\ \wedge \text{ Eats(x,y)} & \Rightarrow & \text{Carrot(y)} \\ & & \wedge \text{ HasProperty(y,eaten)} \\ & & \wedge \ (\forall \text{ w Eats-In(x,y,w)} \\ & & \qquad \Rightarrow [\text{Salad(w)} \vee \text{Nothing(w)}]) \end{array}$$

4.6.3 SNePS Interpretation.

```
(describe (assert forall $x6
  forall $y6
  forall $w6
  &ant (build member *x6
      class Person)
  &ant (build member *y6
      class TypicalCarrot)
  &ant (build rel Eats
      object1 *x6
      object2 *y6)
  cq (build min 3
```

```
   max 3
   arg (build member *y6
      class Carrot)
   arg (build object *y6
      property eaten)
   arg (build
min 1
max 1
arg (build rel Eats-In
   object1 *x6
   object2 *y6
   object3 (build
    member *w6
    class Salad))
arg (build rel Eats-In
   object1 *x6
   object2 *y6
   object3 (build
    member *w6
    class Nothing))))))
```

4.7 Sentence 7.

They also eat boiled carrots.

4.7.1 Informal Discussion and/or Paraphrase.

This sentence is straightforward. Again we are concerned with a typical situation so we will use the "typical carrot". The property of being boiled is simply a property like any other. We can paraphrase the sentence as follows: *Typically people eat carrots that are boiled.*

4.7.2 First-Order Logic Representation.

⟦`boiled`⟧ is the property of being boiled.

FOL representation follows:

$$\forall \text{ x,y Person(x)} \wedge \text{TypicalCarrot(y)} \wedge \text{Eats(x,y)} \Rightarrow \text{Carrot(y)} \wedge \text{HasProperty(y,boiled)}$$

4.7.3 SNePS Interpretation.

```
(describe (assert forall $x7
  forall $y7
  &ant (build member *x7
      class Person)
  &ant (build member *y7
      class TypicalCarrot)
```

```
&ant (build rel Eats
    object1 *x7
    object2 *y7)
cq (build min 2
  max 2
  arg (build member *y7
     class Carrot)
  arg (build object *y7
     property boiled))))
```

4.8 Sentence 8.

In some parts of the world, carrots have been roasted, ground, and used as a substitute for coffee.

4.8.1 Informal Discussion and/or Paraphrase.

The surface structure of this sentence suggests that three separate (and unrelated) actions are being discussed. However, it seems clear that the actual intention of the author was to convey knowledge about a sequential process. That is, in some parts of the world, carrots are *first* roasted, and *subsequently* ground, and the ground-up roasted carrots are then used as a substitute for coffee. Discussion of this issue can be found in the section on "General Remarks", above, as can a discussion of the problems in representing "some" in a way that captures the sense of the English usage here. There really is no good way to address the latter issue. I have chosen to handle it by introducing a class consisting of those regions where carrots are substituted for coffee, named Carrot-For-Coffee-Region. This is not a well-defined class, but without more information or a new logical theory of the expression of "some", I think it is a reasonably good expression of the idea. The sentence can be paraphrased as follows: *There is the world and it has parts. There is a class that is a collection of all regions where carrots are substituted for coffee. Typical carrots in those regions are subjected to a sequence of roasting, grinding, and use as a substitute for coffee. Typical carrots in those regions are a substitute for coffee. Some individuals specific to the carrot are assumed to be the agents performing the actions in the sequence.*

Representation of the sequence of actions is a bit difficult in first-order logic. SNePS has a variety of standard case framse intended to represent plans and actions (Shapiro et al:1992-94). However these are properly intended to represent the actions of the SNePS agent and do not seem to be intended for the representation of the actions of external individuals. In order to minimize my own confusion I have chosen to stay with normal predicates and to avoid the standard case frames. For the first order logic representation I have adopted a three-position predicate that represents their place in the sequence through the third argument.

4.8.2 First-Order Logic Representation.

⟦`Carrot-For-Coffee-Region(x)`⟧ is the proposition that the individual x is a member of the class of Carrot-For-Coffee-Regions.

⟦`In(x,y)`⟧ is that the individual x is located in the region denoted by y.

⟦`Perform-Act(x,y,z)`⟧ is the proposition that the individual x performs action y as the zth act in a possible sequence of actions.

⟦`Substitute(x,y)`⟧ is the proposition that the individual x substitutes for the individual y.

⟦`world`⟧ is the world (geographically speaking).

⟦`coffee`⟧ is the substance coffee.

⟦`Roast(x)`⟧ is the act of roasting x.

⟦`Grind(x)`⟧ is the act of grinding x.

⟦`Make-Use(x)`⟧ is the act of using x.

FOL representation follows:

$$\begin{array}{lll} \forall \text{ x,p HasPart(world, p)} & & \\ \wedge \text{ Carrot-For-Coffee-Region(p)} & & \\ \wedge \text{ TypicalCarrot(x)} \wedge \text{In(x,p)} & \Rightarrow & \text{Carrot(x)} \\ & & \wedge \text{ Perform-Act(f8(x), Roast(x),1)} \\ & & \wedge \text{ Perform-Act(g8(x), Grind(x),2)} \\ & & \wedge \text{ Perform-Act(h8(x), Make-Use(x),3)} \\ & & \wedge \text{ Substitute(x, coffee)} \end{array}$$

4.8.3 SNePS Interpretation.

```
(describe (assert forall $x8
  forall $p8
  &ant (build rel HasPart
      object1 world
      object2 *p8)
  &ant (build member *p8
      class Carrot-For-Coffee-Region)
  &ant (build member *x8
      class TypicalCarrot)
  &ant (build rel In
      object1 *x8
      object2 *p8)
  cq (build min 5
    max 5
    arg (build member *x8
       class Carrot)
    arg (build rel Perform-Act
       object1 (build a1 *x8
      Skf first-act-x8)
       object2 (build perform Roast
      object *x8)
                                    object3 1)
    arg (build rel Perform-Act
       object1 (build a1 *x8
      Skf second-act-x8)
       object2 (build perform Grind
      object *x8)
                                    object3 2)
    arg (build rel Perform-Act
       object1 (build a1 *x8
      Skf third-act-x8)
       object2 (build perform Make-Use
```

```
  object *x8)
                                 object3 3)
arg (build rel Substitute
   object1 *x8
   object2 coffee))))
```

4.9 Sentence 9.

The plant's thick, lacy leaves and long stems are sometimes chopped up and sprinkled on meats to improve flavor.

4.9.1 Informal Discussion and/or Paraphrase.

The use of "the plant" to refer to a member of the class of carrots illustrates a frequently found technique in writing in English. The writer can rely on the reader to continue the focus of attention from sentence to sentence, at least within the same paragraph of text. The "carrots" which were the subject of the previous sentence occupy the focus of the reader's attention as this sentence is encountered. When this sentence is read, however, the subject is described as "the plant" with no explicit link between the carrots of the previous sentence and the plant of this sentence. For humans, such a transition is fairly simple. The human reader knows from the first sentence of the article that the overall subject of the text is "carrot" and that a carrot is a plant. Further, the subject of the previous sentence was a subclass of carrots. Moreover, there have been no other plants mentioned in the article so far. Therefore the reference to *the* plant must be a reference to carrot.

While this transition between representations of the same subject is fairly easy for humans to make, it seems rather difficult for a machine. The chain of reasoning involved requires memory about the prior text, reasoning about subclass-superclass relationships (carrot is a subclass of plant), and a fairly deep understanding of the role of the English article "the" (which here is used to identify not a specific individual but a generic individual representative of a class). In terms of a first-order logic representation we need to reintroduce explicitly that we are discussing the class of carrots—if we do not do this we run the risk of making claims about the class of plants that would not be a true representation of the knowledge the author intended to express. This sort of implicit information (that "plant" actually means "carrot") is one of the main reasons that knowledge representation is not an easily automatable process.

The English word "sometimes" is somewhat difficult in terms of its first-order logic representation. The sense of the word is that there are occasions where the claim that follows is true, and that these are a proper subset of all occasions. This suggests a subclass-superclass relationship, but how can we use a subclass to represent time? The notion of time as a set of occasions is naive at best. The notion of an occasion is ill-defined. How long is an "occasion"? How do we order occasions? Can they overlap? Certainly the author can rely on human readers to have a more rich understanding of time than as a set of occasions. In order to avoid an overly complicated and largely irrelevant representation of the nature of time, however, our representation will look on time as a set of occasions without worrying about exactly what an "occasion" means.

In terms of the first-order logic representation, we would seem to need to represent that occasions exist in which the claim is true and that other occasions exist in which the claim is not true. By introducing the later can we make it clear that "sometimes" is a proper subset of the set of all occasions. But this approach has an obvious problem—by saying that there exist some occasions when the sentence is true and others when it is not true we have really said nothing. That is to say, we have simply stated a tautology that adds nothing to our ability to reason about carrots. In light of this, it seems wise to eliminate the representation of “sometimes” altogether and simply to claim that there *exist* occasions in which the sentence is true.

The notion that the leaves and stems of the carrot are chopped up and sprinkled on meats is similar to the sequence of events described in Sentence 8, in which the process of roasting *et cetera* was described. That is, this represents a sequence of actions, first chopping and subsequently sprinkling. This sequence of actions is undertaken for a purpose, specifically for the purpose of improving the flavor of meat. Notice that there is no obvious, explicit indication that the phrase “to improve flavor” refers to the flavor of the meat. Here the author is relying on the general experience of the (human) reader to complete the implicit meaning of the phrase. As written, the phrase “to improve flavor” is quite ambiguous. Does it refer to the flavor of the meats? Does it refer to the flavor of the carrot? How about the flavor of the leaves and stems? If this sentence were presented to a human from a strictly vegetarian culture, it is not clear that that reader would immediately make the “obvious” assumption that the flavor of the meats are being discussed Though the word “meats” is almost always used to refer to animal flesh as food, the general experience of the reader has to contain a “script” so to speak of seasoning food by sprinkling a seasoning agent upon it.

The sentence can then be paraphrased as follows: *A carrot is a plant and has parts that are leaves and stems. The leaves are thick and lacy. The stems are long. There is a class of occasions. There is a proper subset of the class of occasions in each member of which the leaves and stems are first chopped up and subsequently sprinkled on meats for the purpose of improving the flavor of the meat. Some individuals specific to the carrot are assumet to be the agents performing the actions in the sequence.*

4.9.2 First-Order Logic Representation.

⟦`Leaf(x)`⟧ is the proposition that the individual x is a member of the class of leaves.

⟦`Stem(x)`⟧ is the proposition that the individual x is a member of the class of stems.

⟦`thick`⟧ is the property of being thick.

⟦`lacy`⟧ is the property of being lacy.

⟦`long`⟧ is the property of being long.

⟦`Occasion(x)`⟧ is the proposition that the individual x is an member of the class of all occasions existing throughout time.

⟦`Action-Occasion(x,y)`⟧ is the proposition that the action represented by x occurs during the occasion represented by y.

⟦`Chop(x)`⟧ is the action of chopping x.

⟦`Sprinkle-On(x,y)`⟧ is the action of sprinkling x onto y.

⟦`meats`⟧ is a collective individual representing a specific collection of meats.

⟦`Purpose(x,y)`⟧ is the proposition that the purpose of the action x is y.

⟦`Improve-Flavor(x)`⟧ is the proposition that the flavor of x is improved.

FOL representation follows:

$$
\begin{aligned}
\forall \text{ x Carrot(x)} \quad \Rightarrow \quad & \exists \text{ y1,y2,y3,y4} \\
& \text{Plant(x)} \\
& \wedge \text{ HasPart(x,f9(x))} \\
& \wedge \text{ Leaf(f9(x))} \\
& \wedge \text{ HasProperty(f9(x),thick)} \\
& \wedge \text{ HasProperty(f9(x),lacy)} \\
& \wedge \text{ HasPart(x,g9(x))} \\
& \wedge \text{ Stem(g9(x))} \\
& \wedge \text{ HasProperty(g9(x),long)} \\
& \wedge \text{ Perform-Act(h9(x),Chop(f9(x)),1)} \\
& \wedge \text{ Action-Occasion(Chop(f9(x)),y1)} \\
& \wedge \text{ Perform-Act(i9(x),Chop(g9(x)),1)} \\
& \wedge \text{ Action-Occasion(Chop(g9(x)),y2)} \\
& \wedge \text{ Perform-Act(j9(x),Sprinkle-On(f9(x),meats),2)} \\
& \wedge \text{ Action-Occasion(Sprinkle-On(f9(x),meats),y3)} \\
& \wedge \text{ Purpose(Sprinkle-On(f9(x),meats),Improve-Flavor(meats))} \\
& \wedge \text{ Perform-Act(k9(x),Sprinkle-On(g9(x),meats),2)} \\
& \wedge \text{ Action-Occasion(Sprinkle-On(g9(x),meats),y4)} \\
& \wedge \text{ Purpose(Sprinkle-On(g9(x),meats),Improve-Flavor(meats))}
\end{aligned}
$$

4.9.3 SNePS Interpretation.

```
(describe (assert forall $x9
  ant (build member *x9
     class Carrot)
  cq (build min 18
    max 18
    arg (build member *x9
       class Plant)
    arg (build rel HasPart
       object1 *x9
       object2 (build a1 *x9
      Skf leaf-of-x9))
    arg (build member leaf-of-x9
       class Leaf)
    arg (build object leaf-of-x9
       property thick)
    arg (build object leaf-of-x9
       property lacy)
    arg (build rel HasPart
       object1 *x9
       object2 (build a1 *x9
      Skf stem-of-x9))
    arg (build member stem-of-x9
       class Stem)
    arg (build object stem-of-x9
       property long)
    arg (build rel Perform-Act
       object1 (build a1 *x9
      Skf first-act-x9)
       object2 (build perform Chop
      object leaf-of-x9)
```

```
                                    object3 1)
arg (build rel Action-Occasion
   object1 (build perform Chop
  object leaf-of-x9)
   object2 #occasion1)
arg (build rel Perform-Act
   object1 (build a1 *x9
  Skf first-act-x9)
   object2 (build perform Chop
  object stem-of-x9)
                                    object3 1)
arg (build rel Action-Occasion
   object1 (build perform Chop
  object stem-of-x9)
   object2 #occasion2)
arg (build rel Perform-Act
   object1 (build a1 *x9
  Skf second-act-x9)
   object2 (build perform Sprinkle-On
  object1 leaf-of-x9
  object2 meats)
                                    object3 2)
arg (build rel Action-Occasion
   object1 (build perform Sprinkle-On
  object1 leaf-of-x9
  object2 meats)
   object2 #occasion3)
arg (build rel Purpose
   object1 (build perform Sprinkle-On
  object1 leaf-of-x9
  object2 meats)
   object2 (build perform Improve-Flavor
  object meats))
arg (build rel Perform-Act
   object1 (build a1 *x9
  Skf second-act-x9)
   object2 (build perform Sprinkle-On
  object1 stem-of-x9
  object2 meats)
                                    object3 2)
arg (build rel Action-Occasion
   object1 (build perform Sprinkle-On
  object1 stem-of-x9
  object2 meats)
   object2 #occasion4)
arg (build rel Purpose
   object1 (build perform Sprinkle-On
  object1 stem-of-x9
  object2 meats)
   object2 (build perform Improve-Flavor
  object meats)))))
```

4.10 Sentence 10.

Carrots are grown from tiny seeds planted from $1\frac{1}{2}$ to 2 feet (46 to 61 centimeters) apart.

4.10.1 Informal Discussion and/or Paraphrase.

This sentence could be considered primarily as a description of an action of carrots (a "grow" action) or as a description of a relationship between carrots and seeds (a "grow from" relationship). The actual knowledge incorporates both aspects but to my thinking the second emphasis is more important. That is, the relationship between individuals that are carrots and individuals that are seeds is the primary emphasis of the sentence. This is suggested by the use of the passive voice "carrots *are grown*". We know from general experience that any individual carrot is probably grown from a single seed but this is not explicitly provided by the text of the sentence. In the first order logic representation though we can certainly say that for any carrot there must exist at least one seed which is proper to that carrot and from which that carrot is grown. The idea of a "tiny seed" is vague and dependent on the general experience of the reader. The author assumes that the reader has some notion of either typical or representative seeds to give a sense of scale—"tiny seeds" are then tiny in relation to the idea of a typical seed. While this may be a reasonable communication between the author and a human reader, it may be much less successful if the communication is with an artificial entity. The size scale for "seed" objectively runs from very tiny objects of less than one millimeter width to very large coconuts of more than a dozen centimeters width. The *common sense* that the author assumes of his human reader may not be common to all readers. One approach to representing the concept of "tiny seed" is to posit the existence of a "structured individual" representing a subclass of seeds called "tiny seeds". In the SNePS Research Group this approach has been used to represent similar ideas, for example the notion of "small elephant" in the sentence "Clyde is a small elephant." It is clear that in both the case of "tiny seed" and "small elephant" (or "huge ant" for that matter) that the size quantification is to be applied to the *typical* case for the object described, even though the size of the typical case is not part of the explicit knowledge contained in the text. We can paraphrase the sentence as follows: *There is a class of seeds that has a subclass of seeds which are tiny and are planted from $1\frac{1}{2}$ to 2 feet apart. For each carrot there exists a member of this subclass such that there is a "grow from" relationship between the carrot and this member.*

4.10.2 First-Order Logic Representation.

⟦`Seed(x)`⟧ is the proposition that the individual x is a member of the class of seeds.

⟦`TinySeed(x)`⟧ is the proposition that the individual x is a member of the class of tiny-seeds.

⟦`Distance(x,y)`⟧ is the proposition that the individual x is a distance.

⟦`1`$\frac{1}{2}$`-feet`⟧ is an individual representing a distance of $1\frac{1}{2}$ feet.

⟦`2-feet`⟧ is an individual representing a distance of 2 feet.

⟦`GreaterThanOrEqualTo(x,y)`⟧ is the proposition that the magnitude of the individual x is greater than or equal to the magnitude of the individual y (assuming only a single dimension for comparison exists).

⟦`LessThanOrEqualTo(x,y)`⟧ is the proposition that the magnitude of the individual x is less than or equal to the magnitude of the individual y (assuming only a single dimension for comparison exists).

⟦`PlantedApart(x,y,z)`⟧ is the proposition that the individuals x and y are planted a distance z apart from each other.

⟦`GrowFrom(x,y)`⟧ is the proposition that the individual x grows from the individual y.

FOL representation follows:

$$\forall\, x,y\ \mathrm{Carrot}(x) \wedge \mathrm{Carrot}(y) \Rightarrow \begin{array}{l} \mathrm{TinySeed}(f10(x)) \\ \wedge\ \mathrm{Seed}(f10(x)) \\ \wedge\ \mathrm{TinySeed}(f10(y)) \\ \wedge\ \mathrm{Seed}(f10(y)) \\ \wedge\ \mathrm{Distance}(g10(x,y)) \\ \wedge\ \mathrm{PlantedApart}(x,y,g10(x,y)) \\ \wedge\ \mathrm{GreaterThanOrEqualTo}(g10(x,y),1\tfrac{1}{2}\text{-feet}) \\ \wedge\ \mathrm{LessThanOrEqualTo}(g10(x,y),2\text{-feet}) \end{array}$$

4.10.3 SNePS Interpretation.

```
(describe (assert forall $x10
  forall $y10
  &ant (build member *x10
      class Carrot)
  &ant (build member *y10
      class Carrot)
  cq (build min 9
    max 9
    arg (build member (build a1 *x10
     Skf seed-of-x10)
       class TinySeed)
    arg (build member seed-of-x10
       class Seed)
    arg (build member (build a1 *y10
     Skf seed-of-y10)
       class TinySeed)
    arg (build member seed-of-y10
       class Seed)
    arg (build member (build a1 *x10
     a2 *y10
     Skf distance-of-x10-y10)
       class Distance)
    arg (build rel PlantedApart
       object1 *x10
       object2 *y10
       object3 distance-of-x10-y10)
    arg (build rel GreaterThanOrEqualTo
       object1 distance-of-x10-y10
       object2 1-1/2-feet)
    arg (build rel LessThanOrEqualTo
       object1 distance-of-x10-y10
       object2 2-feet))))
```

4.11 Sentence 11.

They grow best in deep, rich soils that contain sand or muck.

4.11.1 Informal Discussion and/or Paraphrase.

Here the "they" refers to the carrots described in the previous sentence. We can say that the carrots "grow in" such soils easily enough but how do we say that they "grow *best* in", in other words, how do we represent the modification that the adverb "best" imposes on the action of "grow in". One possible approach is to say that all carrots that are grown in such soils are better than those that are grown in soils which do not have these characteristics. Note that the word "rich" is ambiguous. It could mean that the soils possess wealth (perhaps they contain gold or rubies). The knowledge the author is trying to communicate is that the soils are *"rich" in the sense that humans conventionally use this term when describing soil.* That is to say, the phrase "rich soils" *appears* unambiguous to humans because we have a sense that this phrase has a unity to it—that it is in effect an idiom describing soils that have certain conventionally expected characteristics (high content of organic material and minerals, good moisture content and retention, and so forth). This is an example of the author's reliance on "common sense" as an integral part of the communication. A non-human intelligent entity attempting to interpret this phrase would probably come up with the common sense interpretation eventually but might not do so without ambiguity. Fortunately for the purpose of this project we can confidently assert that the common sense interpretation is the only one intended to be communicated by the author. We can paraphrase the sentence as follows: *The class of soils has two subclasses. The members of the first subclass have the properties of being deep and rich and containing either the substance sand or the substance muck or both. The members of the second subclass have the properties of being either not deep or not rich or contain neither sand nor muck. All carrots grown in soils that are members of the first subclass are better than all carrots grown in soils that are members of the second subclass.*

4.11.2 First-Order Logic Representation.

⟦`Soil(x)`⟧ is that the individual x is a member of the class of soils.

⟦`Deep(x)`⟧ is the proposition that the individual x has the property of being deep.

⟦`Rich(x)`⟧ is the proposition that the individual x has the property of being rich.

⟦`GrowIn(x,y)`⟧ is the proposition that the individual x grows in the individual y.

⟦`Better(x,y)`⟧ is the proposition that the individual x is better than the individual y (assuming only a single dimension for comparison exists).

FOL representation follows:

∀ w,x,y,z Carrot(w) ∧ Carrot(x)
∧ Soil(y) ∧ Deep(y) ∧ Rich(y)
∧ Substance(f11(y),sand)
∧ Substance(g11(y),muck)
∧ [Contains(y,f11(y)) ∨ Contains(y,g11(y))]
∧ GrowsIn(w,y)
∧ Soil(z)
∧ Substance(f11(z),sand)
∧ Substance(g11(z),muck)
∧ [¬Deep(z) ∨ ¬Rich(z)
∨ ¬Contains(z,f11(z))
∨ ¬Contains(z,g11(z))]
∧ GrowsIn(x,z) ⇒ Better(w,x)

4.11.3 SNePS Interpretation.

```
(describe (assert forall $w11
  forall $x11
  forall $y11
  forall $z11
  &ant (build member *w11
      class Carrot)
  &ant (build member *x11
      class Carrot)
  &ant (build member *y11
      class Soil)
  &ant (build object *y11
      property deep)
  &ant (build object *y11
      property rich)
  &ant (build rel Substance
      object1 (build a1 *y11
     Skf sand-of-y11)
      object2 sand)
  &ant (build rel Substance
      object1 (build a1 *y11
     Skf muck-of-y11)
      object2 muck)
  &ant (build min 1
      max 2
      arg (build rel Contains
 object1 *y11
 object2 sand-of-y11)
      arg (build rel Contains
 object1 *y11
 object2 muck-of-y11))
  &ant (build rel GrowsIn
      object1 *w11
      object2 *y11)
  &ant (build member *z11
      class Soil)
  &ant (build rel Substance
      object1 (build a1 *z11
     Skf sand-of-z11)
      object2 sand)
  &ant (build rel Substance
      object1 (build a1 *z11
     Skf muck-of-z11)
      object2 muck)
  &ant (build min 1
      max 2
      arg (build
   min 0 max 1
   arg (build object *z11
      property deep)
   arg (build object *z11
```

```
      property rich))
      arg (build
   min 0 max 0
   arg (build rel Contains
      object1 sand
      object2 sand-of-z11)
   arg (build rel Contains
      object1 muck
      object2 muck-of-z11)))
  &ant (build rel GrowsIn
      object1 *w11
      object2 *z11)
  cq (build rel Better
    object1 *w11
    object2 *x11)))
```

4.12 Sentence 12.

Carrots can survive cool winters and can withstand much summer heat.

4.12.1 Informal Discussion and/or Paraphrase.

This is a statement about the abilities of carrots. That is to say that while the word "can" is a verb the knowledge represented by this sentence is not so much about the *actions* of carrots as about *properties* of the members of the class of carrots. Carrots have the property that they are able to survive cool winters and the property that they can withstand much summer heat. In terms of the SNePS representation we might represent this knowledge by the standard object-property case frame to indicate that a carrot object has an ability property. The ability object however is only meaningful if it is an ability *to do* something. This suggests that the ability property must be represented as a proposition, perhaps something such as *a carrot individual has a can-survive relation to cool-winter individuals.* If we choose to represent this proposition, then the object-property case frame becomes a bit redundant—the same knowledge is represented by the proposition alone. Representation of the phrase "much summer heat" requires the non-first order quantification "much". I have found no truly convincing way to represent such quantification. In terms of the SNePS representation perhaps a proposition that a structured individual representing "summer heat" has a property "much-heat" is as good as any. We can paraphrase the sentence as follows: *There is a class of winters that has a subclass of winters that are cool. There is a class of summer-heats some members of which have the property much-heat. All carrots have a can-survive relation to cool winters and have a can-withstand relation to those summer-heats that have the property of much-heat.*

4.12.2 First-Order Logic Representation.

⟦`Winter(x)`⟧ is that the individual x is a member of the class of winters.

⟦`CoolWinter(x)`⟧ is that the individual x is a member of the class of cool-winters.

⟦`Heat(x)`⟧ is that the individual x is a member of the class of heats.

⟦`SummerHeat(x)`⟧ is that the individual x is a member of the class of summer-heats.

⟦`much-heat`⟧ is the property of having much heat.

⟦`CanSurvive(x,y)`⟧ is the proposition that the individual x can survive interaction with the individual y.

⟦`CanWithstand(x,y)`⟧ is the proposition that the individual x can withstand interaction with the individual y.

FOL representation follows:

$$\forall \text{ x,y,z Carrot(x)} \wedge \text{CoolWinter(y)} \wedge \text{SummerHeat(z)} \wedge \text{HasProperty(z,much-heat)} \Rightarrow \text{Winter(y)} \wedge \text{CanSurvive(x,y)} \wedge \text{Heat(z)} \wedge \text{CanWithstand(x,z)}$$

4.12.3 SNePS Interpretation.

```
(describe (assert forall $x12
  forall $y12
  forall $z12
  &ant (build member *x12
      class Carrot)
  &ant (build member *y12
      class CoolWinter)
  &ant (build member *z12
      class SummerHeat)
  &ant (build object *z12
      property much-heat)
  cq (build min 4
    max 4
    arg (build member *y12
       class Winter)
    arg (build rel CanSurvive
       object1 *x12
       object2 *y12)
    arg (build member *z12
       class Heat)
    arg (build rel CanWithstand
       object1 *x12
       object2 *z12))))
```

4.13 Sentence 13.

Gardeners in the northern part of the United States often raise summer and fall crops of carrots.

4.13.1 Informal Discussion and/or Paraphrase.

Here we have a question about whether the knowledge is actually about carrots or about gardeners. The surface presentation of the sentence suggests that gardeners are the actual subject of discussion. Indeed if this sentence were presented in isolation that would be the "natural" conclusion. Only the fact that the sentence appears in the context of an article about carrots lets us realize that carrots are the actual focus of knowledge. In light of this we might reasonably reexpress the sentence as something like "Carrots often *are raised as* summer and fall crops *by* gardeners ... " to more clearly indicate that the focus is on carrots. The *knowledge* communicated is essentially the same in either text expression. However, passive voice verbs present their own problems and the surface structure of the original sentence clearly puts forth "gardeners" as its subject, so we will represent this as a statement about gardeners.

The geographic location of these gardeners is given as "the northern part of the United States". Certainly we could express an entity called "the United States" that has a component that can be identified as "the northern part" but since this phrase is used only in this sentence and is not really related to any other sentence in the article, I have chosen simply to identify an individual called "northern-part-of-US" without concerning myself with further analysis. Clearly if it were important to be able to reason about where carrots are grown it may be appropriate to refine this rather coarse-grained representation, but for now this seems adequate and further refinement strikes me as unprofitable for the task at hand.

The difficulty of representing the time/occasion quantifier "often" has already been discussed at length in the context of the similar quantifier "sometimes" (see the Informal Discussion of Sentence 9 above). There is really no way to represent such "fuzzy" quantification in first order logic, at least none that I have found convincing. We can only say that there are some occasions in which the claims of the sentence are true and some in which they are not. Unfortunately, this would lead to an exhaustion of cases and a resulting useless tautology. There is no way to compare the cardinality of the two subsets of occasions since "often" is too vague a measure ("often" could equally well describe a majority of occasions as well as a "large" minority of occasions—there is simply no way to pin it down). To be frank, without the introduction of suspicious predicates like *OftenRaise(x,y)* I do not think this concept of "often" can be expressed in standard first order logic. While the sense of the English word "sometimes" is really fairly close to the "exists" quantifier of first order logic, "often" really is not.

The notion of "crops" is an interesting one. The author of the article clearly expects the reader to know that a "crop" is a collective noun describing a group of carrots. This is a reasonable expectation for humans, but is less reasonable for machines. Without a fairly well developed world knowledge concerning the habits of gardeners the notion that they "raise summer and fall crops" is somewhat obscure.

The paraphrase of this sentence, bearing in mind all these problems, follows: *There is a set of crops that has a subset called summer-crops and a subset called fall-crops. There is a class of gardeners some of the members of which are located in the northern part of the United States. Each such gardener is in an often-raise relation to some members of the class of summer-crops and fall-crops. The members of these particular crops are all carrots.*

4.13.2 First-Order Logic Representation.

⟦`Gardener(x)`⟧ is the proposition that the individual x is a member of the class of gardeners.

⟦`northern-part-of-US`⟧ is the region described by the phrase "the northern part of the United States".

⟦`Crop(x)`⟧ is the proposition that the individual x is a member of the class of crops.

⟦`SummerCrop(x)`⟧ is the proposition that the individual x is a member of the class of summer-crops.

⟦`FallCrop(x)`⟧ is the proposition that the individual x is a member of the class of fall-crops.

⟦`OftenRaise(x,y)`⟧ is the proposition that the individual x "often raises" a "thing" denoted by y.

⟦`ConstituentOf(x,y)`⟧ is the proposition that the individual x is a constituent of the collective individual y.

FOL representation follows:

$$\begin{array}{ll} \forall\ x,y,z\ \text{Gardener}(x) & \\ \wedge\ \text{In}(x,\text{northern-part-of-US}) & \\ \wedge\ \text{SummerCrop}(f13(x)) & \\ \wedge\ \text{FallCrop}(g13(x)) \quad \Rightarrow & \text{Crop}(f13(x)) \\ & \wedge\ \text{OftenRaise}(x,f13(x)) \\ & \wedge\ [\text{ConstituentOf}(y,f13(x)) \Rightarrow \text{Carrot}(y)] \\ & \wedge\ \text{Crop}(g13(x)) \\ & \wedge\ \text{OftenRaise}(x,g13(x)) \\ & \wedge\ [\text{ConstituentOf}(z,g13(x)) \Rightarrow \text{Carrot}(z)] \end{array}$$

4.13.3 SNePS Interpretation.

```
(describe (assert forall $x13
  forall $y13
  forall $z13
  &ant (build rel In
      object1 *x13
      object2 northern-part-of-US)
  &ant (build member (build a1 *x13
    Skf summer-crop-of-x13)
      class SummerCrop)
  &ant (build member (build a1 *x13
    Skf fall-crop-of-x13)
      class FallCrop)
  cq (build min 6
    max 6
    arg (build member summer-crop-of-x13
       class Crop)
    arg (build rel OftenRaise
       object1 *x13
       object2 summer-crop-of-x13)
    arg (build ant (build rel ConstituentOf
  object1 *y13
  object2 summer-crop-of-x13)
       cq (build member *y13
 class Carrot))
```

```
    arg (build member fall-crop-of-x13
       class Crop)
    arg (build rel OftenRaise
       object1 *x13
       object2 fall-crop-of-x13)
    arg (build ant (build rel ConstituentOf
  object1 *y13
  object2 fall-crop-of-x13)
       cq (build member *y13
 class Carrot)))))
```

4.14 Sentence 14.

Each crop takes about 100 days to grow.

4.14.1 Informal Discussion and/or Paraphrase.

The use of the collective noun "crop" here is interesting. We should actually understand this as something like "each individual member of the collective crop takes about 100 days to grow" since physical growth is not something that an abstract collective noun can actually be said to accomplish. The author's meaning is clear to human readers because human readers recognize that the collective is said to have a behavior if all of its members have that behavior. This interpretation may be supported by some interpretations of English grammar, but the more important support for it is the common sense understanding of collections and the customary, idiomatic way of describing their behavior.

The time measure of "about 100 days" is obviously vague. It is most easily represented as an individual expressing a single duration, albeit one that cannot be precisely measured. The human reader can be assumed to know that in reality a *range* of durations are intended by this phrase rather than a single duration of uncertain extent. Without a highly elaborated scheme for representing fuzzy quantities and statistical spreads, however, a representation of a single uncertain duration should be adequate to capture the notion. Note that "to grow" is intended to convey the idea "to grow *to maturity*" that the literal text does not make entirely clear. The literal text allows a possible interpretation that 100 days are required before growth begins. Once again the author is relying on the common sense use of a phrase in context to convey his meaning. Once again there is an ambiguity in this technique that could present difficulties for a non-human trying to understand the text.

Since this sentence refers back to the prior sentence, it may be appropriate to combine this sentence with the previous one so that the Skolem functions that describe the crops can be retained here. That is, when this sentence refers to "each crop" it is, strictly speaking, referring to specific intensional individuals described in the previous sentence. Rather than combining the sentences, however, we will simply restate the previous first order logic representation, adding the additional knowledge that the members of the crops require about 100 days to grow. We paraphrase the sentence as follows: *(from the previous sentence) There is a set of crops that has a subset called summer-crops and a subset called fall-crops. There is a class of gardeners some of the members of which are located in the northern part of the United States. Each such gardener is in an often-raise relation to some members of the class of summer-crops and fall-crops. The members of these particular crops are all carrots. (new information) Each such carrot requires about 100 days to grow.*

4.14.2 First-Order Logic Representation.

⟦`about-100-days`⟧ is an individual duration of about 100 days length.

⟦`RequiresToDo(x,y,z)`⟧ is the proposition that the individual x requires individual y in order for x to perform action z.

⟦`GrowToMaturity(x)`⟧ is the action of x growing to maturity.

Note that since we are referring to the crops described in the previous sentence, the Skolem constants that represent those crops (namely f13(x) and g13(x)) are repeated here.

FOL representation follows:

$$
\begin{array}{lll}
\forall\ x,y,z\ \text{Gardener}(x) & & \\
\wedge\ \text{In}(x,\text{northern-part-of-US}) & & \\
\wedge\ \text{SummerCrop}(f13(x)) & & \\
\wedge\ \text{FallCrop}(g(x)) & \Rightarrow & \text{Crop}(f13(x)) \\
 & & \wedge\ \text{OftenRaise}(x,f13(x)) \\
 & & \wedge\ \{\text{ConstituentOf}(y,f13(x)) \Rightarrow \\
 & & \quad [\text{Carrot}(y) \\
 & & \quad \wedge\ \text{RequiresToDo}(y,\text{about-100-days}, \\
 & & \qquad \text{GrowToMaturity}(y))]\} \\
 & & \wedge\ \text{Crop}(z) \\
 & & \wedge\ \text{OftenRaise}(z,g13(x)) \\
 & & \wedge\ \{\text{ConstituentOf}(z,g13(x)) \Rightarrow \\
 & & \quad [\text{Carrot}(z) \\
 & & \quad \wedge\ \text{RequiresToDo}(z,\text{about-100-days}, \\
 & & \qquad \text{GrowToMaturity}(z))]\}
\end{array}
$$

4.14.3 SNePS Interpretation.

```
;;
;; Note that the crops referred to are created by sentence 13
;;   so their named nodes (summer-crop-of-x13 and fall-crop-of-x13)
;;   are reused
;;

(describe (assert forall $x14
  forall $y14
  forall $z14
  &ant (build member *x14
      class Gardener)
  &ant (build rel In
      object1 *x14
      object2 northern-part-of-US)
  &ant (build member summer-crop-of-x14
      class SummerCrop)
  &ant (build member fall-crop-of-x14
      class FallCrop)
  cq (build min 6
    max 6
    arg (build member summer-crop-of-x13
        class Crop)
```

```
    arg (build rel OftenRaise
       object1 *x14
       object2 summer-crop-of-x13)
    arg (build
 ant (build rel ConstituentOf
    object1 *y14
    object2 summer-crop-of-x13)
 cq (build min 2
   max 2
   arg (build member *y14
      class Carrot)
   arg (build
rel RequiresToDo
object1 *y14
object2 about-100-days
object3 (build
 perform GrowToMaturity
 object *y14))))
    arg (build member fall-crop-of-x13
       class Crop)
    arg (build rel OftenRaise
       object1 *x14
       object2 fall-crop-of-x13)
    arg (build
 ant (build rel ConstituentOf
    object1 *z14
    object2 fall-crop-of-x13)
 cq (build min 2
   max 2
   arg (build member *z14
      class Carrot)
   arg (build
rel RequiresToDo
object1 *z14
object2 about-100-days
object3 (build
 perform GrowToMaturity
 object *y14)))))))
```

4.15 Sentence 15.

Carrots are native to the Mediterranean region.

4.15.1 Informal Discussion and/or Paraphrase.

This is a rather straightforward sentence. We simply need to represent that the class of carrots is in a "native to" relation to the structured individual represented by "Mediterranean region". Since the sense of the English phrase "native to" here describes a relation between a *class* and an individual (region) we can represent it in first order logic by quantifying over all the individual members of the class (that is, all carrots whatsoever are "native to the Mediterranean region"). The discussion of northern-part-of-the-US above (see Informal Discussion of Sentence 13 above) applies here for the representation of the region. Barring a detailed representation of world geography, an intensional individual representing "the Mediterranian region" will suffice to express this notion.

We paraphrase as follows: *There is a place called "the Mediterranean region". Each carrot in the class of all carrots is native to that place.*

4.15.2 First-Order Logic Representation.

⟦`NativeTo(x,y)`⟧ is the proposition that the individual x is native to the individual region denoted by y.

⟦`Mediterranean-region`⟧ is the individual region identified by the phrase "the Mediterranean region".

FOL representation follows:

$$\forall\ x\ \text{Carrot}(x) \Rightarrow \text{NativeTo}(x,\text{Mediterranean-region})$$

4.15.3 SNePS Interpretation.

```
(describe (assert forall $x15
  ant (build member *x15
     class Carrot)
  cq (build rel NativeTo
    object1 *x15
    object2 Mediterranean-region)))
```

4.16 Sentence 16.

The ancient Greeks and Romans grew carrots that had thin, tough roots.

4.16.1 Informal Discussion and/or Paraphrase.

The human reader is expected to understand that "ancient" in this sentence modifies both "Greeks" and "Romans" (though of course there do exist both non-ancient Greeks and non-ancient Romans) and indicates the time frame of the entire sentence. This is another example of something that seems completely natural in human-to-human communication but that would present some difficulty for a machine. The clue to the fact of a single time context is provided by the verb "grew". The human reader (who can be expected to have some general knowledge of antiquity) understands that this sentence has a time context appropriate to the subjects, that is, that the growing action occurred in the *ancient* past. To what extent should time information be explicitly represented? Much of human understanding of narrative is based on the ability of humans to reason based on implicit knowledge of the time relationships within the narrative. In this case, there is implicit knowledge that a *contrast* is being described between carrots in antiquity and carrots of modern times. These issues are not relevant to the task at hand, since the knowledge representation in this project does not incorporate a sophisticated representation of time. Nonetheless they are important issues for the general question of knowledge representation. We can paraphrase the sentence as follows: *If a member of the class of ancient-Greeks or the class of ancient-Romans grew a carrot, then that carrot has a root and that root has the properties of being thin and tough.*

4.16.2 First-Order Logic Representation.

⟦`Grow(x,y)`⟧ is the proposition that the individual x is grows (in the sense of "raises") the individual y.

⟦`AncientGreek(x)`⟧ is the proposition that the individual x is a member of the class of ancient Greeks.

⟦`AncientRoman(x)`⟧ is the proposition that the individual x is a member of the class of ancient Romans.

⟦`thin`⟧ is the property of being thin.

⟦`tough`⟧ is the property of being tough.

FOL representation follows:

$$\begin{array}{lcl} \forall\ x,y\ \mathrm{Carrot}(x) & & \\ \wedge\ [\mathrm{AncientGreek}(y) \vee \mathrm{AncientRoman}(y)] & & \\ \wedge\ \mathrm{Grows}(y,x) & \Rightarrow & \mathrm{HasPart}(x,f16(x)) \\ & & \wedge\ \mathrm{Root}(f16(x)) \\ & & \wedge\ \mathrm{HasProperty}(f16(x),thin) \\ & & \wedge\ \mathrm{HasProperty}(f16(x),tough) \end{array}$$

4.16.3 SNePS Interpretation.

```
(describe (assert forall $x16
  forall $y16
  &ant (build member *x16
      class Carrot)
  &ant (build min 1
      max 1
      arg (build member *y16
 class AncientGreek)
      arg (build member *y16
 class AncientRoman))
  &ant (build rel Grows
      object1 *y16
      object2 *x16)
  cq (build min 4
    max 4
    arg (build rel HasPart
       object1 *x16
       object2 (build a1 *x16
      Skf root-of-x16))
    arg (build member root-of-x16
       class Root)
    arg (build object root-of-x16
       property thin)
    arg (build object root-of-x16
       property tough))))
```

4.17 Sentence 17.

They used the plants as medicine but not as a food.

4.17.1 Informal Discussion and/or Paraphrase.

The “they” here refers to the ancient Greeks and Romans, the subject of the sentence above, continuing the grammatical subject of that sentence. This interpretation is easy and seems natural to humans, but it is not guaranteed that this is the only interpretation. (See (Grosz, et al.: 1995) for an interesting discussion of how the center of linguistic attention moves in discourse.) It might be that the “they” refers to the carrots rather than to their growers, even though such an interpretation should be discarded when the reference to “the plants” is read. We can paraphrase this sentence as follows: *The members of the class of ancient-Greeks and of the class of ancient-Romans made use of carrots for the purpose of medicine and not for the purpose of food.*

4.17.2 First-Order Logic Representation.

⟦`UseAsMedicine(x)`⟧ is the purpose of using x as medicine.

⟦`UseAsFood(x)`⟧ is the purpose of using x as food.

FOL representation follows:

$$\begin{array}{lll} \forall\ x,y\ \mathrm{Carrot}(x) & & \\ \wedge\ [\mathrm{AncientGreek}(y) & & \\ \quad \vee\ \mathrm{AncientRoman}(y)] & \Rightarrow & \mathrm{Uses}(y,x) \\ & & \wedge\ \mathrm{Purpose}(\mathrm{Make\text{-}Use}(x),\mathrm{UseAsMedicine}(x)) \\ & & \wedge\ \neg\mathrm{Purpose}(\mathrm{Make\text{-}Use}(x),\mathrm{UseAsFood}(x)) \end{array}$$

4.17.3 SNePS Interpretation.

```
(describe (assert forall $x17
  forall $y17
  &ant (build member *x17
      class Carrot)
  &ant (build min 1
      max 1
      arg (build member *y17
 class AncientGreek)
      arg (build member *y17
 class AncientRoman))
  cq (build min 3
    max 3
    arg (build rel Uses
       object1 *y17
       object2 *x17)
    arg (build rel Purpose
       object1 (build perform Make-Use
      object *x17)
       object2 (build purpose-of UseAsMedicine
      object *x17))
```

```
arg (build min 0
   max 0
   arg (build
rel Purpose
object1 (build
 perform Make-Use
 object *x17)
object2 (build
 purpose-of UseAsFood
 object *x17))))))
```

4.18 Sentence 18.

Carrots resembling modern types were later developed in France and were common in Europe by the 1200's.

4.18.1 Informal Discussion and/or Paraphrase.

Here we need to decide how to represent "types" of carrots. It seems that the way to approach this is to make subclasses of the class of all carrots to represent the "types". However, it since a collection of classes is itself a class, we can simplify the representation with a single class to represent the collective "modern types". The carrots that constitute the subject of this sentence collectively form a class any member of which are in a "resemble" relation to all the members of the class of "modern types".

There are some problems with this approach, the most obvious being that "resemble" is a terribly vague term. In what way do these resemble the others? This is unclear. A human reader may be expected to accept the vague term and simply read on, but what is the knowledge that the author intended to convey? It seems fairly clear to me that the author is saying something like this: "In antiquity carrots were different from carrots today—their roots were significantly thinner and tougher than our modern carrots. Carrots that had roots that were less thin and less tough than the ancient carrots, that is, more like modern carrots than like ancient carrots, were developed in France sometime after the period of antiquity (whenever that was) and were commonly found in Europe by the thirteenth century." This is a description of my personal understanding of the knowledge conveyed by this and the two prior sentences. That is to say, when I read these three sentences (in the context of the article) I develop many beliefs about what the knowledge that the author is trying to convey and I have described these beliefs in the quoted section above. However *the contrast I believe the author is making is not explicitly supported by the text of the sentences.* When the author says explicitly that some carrots resemble modern types, the nature of the resemblance is *not* specifically given. For all the reader knows from the explicit text, these carrots may resemble modern carrots in that they are orange or in that they grow in the ground. The existence of a comparison to the thinness and toughness of ancient carrots is nothing more than a (reasonable) conjecture in the mind of the reader, unsupported by the standard rules of grammar or the explicit meaning of the words used. Nevertheless, if that contrast is not actually the knowledge that the author *intended to convey* I would be very surprised indeed. Once again we see how the communication between author and reader relies to a significant extent on common sense (with emphasis on "common" in the sense of "communal") to enable the reader to internally construct knowledge that is only suggested (rather than stated) by the explicit communication.

This sentence is a good example of a significant superiority of SNePS over first order logic as a knowledge-representation language. In SNePS the *class* can be described as having a property or standing in relation to other classes—in first order logic we have to say that the members of a class have the property or that the members of one class stand in a relation to the members of other classes. The surface structure of the English sentence is much more suited to the SNePS approach. The phrase "carrots resembling modern types" is naturally interpreted as something like "a class of carrot resembling modern subclasses of carrot" with the relation "resembling" considered as existing among class objects. First order logic on the other hand requires something more cumbersome like "for all members of the subject carrot paired with each member of the modern subtype of carrots, a resemble relation holds between the members of each pair." To describe these medieval carrots as "common in Europe" is very natural if we are allowed to say that the class is "common" but what does it mean to say that an individual carrot is "common"? We have to use some convoluted approach such as the rather unconvincing "FoundCommonly" predicate below. In the representation of the knowledge in this article, this ability of SNePS to treat classes as objects in their own right is merely convenient; there is no need to actually use second order relations for this small article. SNePS does have the capacity, however, of representing anything that can be represented in normal first order logic as well as to some degree the relations of second order logic.

In order to keep the time representation simple, I will assume that "by the 1200's" can be represented with a "TimeRange" predicate and that "the 1200's", "after-antiquity" and "the present" can all be taken as an individual time loci appropriate for use with this predicate. This is not terribly satisfying—it would be difficult to deduce that the 1200's occurred between antiquity and the present in this scheme—but it has the virtue of simplicity and should be adequate for the task at hand.

The sentence can be paraphrased for purposes of this project as follows: *There is a subclass of carrots that is the class of "modern types" of carrot. There is another subclass of carrots (that is the subject of this sentence) all the members of which resemble all the members of the class of modern types of carrots, and which have a "DevelopedInLocation" relation to France with a "DevelopedInPeriod" after antiquity. For the location Europe and time during or after the 1200's this class has the property of being common.*

4.18.2 First-Order Logic Representation.

⟦`MedievalCarrot(x)`⟧ is the proposition that the individual x is a member of the class of medieval carrots.

⟦`ModernTypeCarrot(x)`⟧ is the proposition that the individual x is a member of the collective class of modern types of carrot.

⟦`Resembles(x,y)`⟧ is the proposition that the individual x resembles the individual y.

⟦`DevelopedInLocation(x,y)`⟧ is the proposition that the individual x was developed in the location denoted by y.

⟦`France`⟧ is the individual location denoted by the name "France".

⟦`DevelopedInPeriod(x,y)`⟧ is the proposition that the individual x was developed during the period denoted by y.

⟦`TimeRange(x,y)`⟧ is an individual time period which begins with the period x and extends continuously through the period y.

⟦`after-antiquity`⟧ is an intensional time period after that denoted by the English word "antiquity" (Sentence 18).

⟦`the-1200's`⟧ is the individual time period denoted by the English phrase "the 1200's", corresponding to the thirteenth century of the common era (a sub-period of the medieval period).

⟦`the-present`⟧ is the individual time period denoted by the English phrase "the present", that is, the period in which modern types of carrots grow.

⟦`CommonInLocation(x,y)`⟧ is the proposition that the individual x has the property of being common in the location denoted by y.

⟦`common`⟧ is the property of being common.

⟦`Europe`⟧ is the individual location denoted by the name "Europe".

FOL representation follows:

∀ x,y MedievalCarrot(x) ∧ ModernTypeCarrot(y)	⇒	Carrot(x) ∧ Carrot(y) ∧ Resembles(x,y) ∧ DevelopedInLocation(x,France) ∧ DevelopedInPeriod(x, TimeRange(after-antiquity, the-present))
∀ x MedievalCarrot(z) ∧ TimeRange(the-1200's, the-present)	⇒	CommonInLocation(z,Europe)
∀ u,w CommonInLocation(u,w)	⇒	HasProperty(u,common)

4.18.3 SNePS Interpretation.

```
(describe (assert forall $x18
  forall $y18
  &ant (build member *x18
      class MedievalCarrot)
  &ant (build member *y18
      class ModernTypeCarrot)
  cq (build min 5
    max 5
    arg (build member *x18
       class Carrot)
    arg (build member *y18
       class Carrot)
    arg (build rel Resembles
       object1 *x18
       object2 *y18)
    arg (build rel DevelopedInLocation
       object1 *x18
       object2 France)
    arg (build rel DevelopedInPeriod
       object1 *x18
       object2
       (build range TimeRange
      range-min after-antiquity
      range-max the-present)))))

(describe (assert forall $z18
  &ant (build member *z18
      class MedievalCarrot)
  &ant (build range TimeRange
      range-min the-1200s
      range-max the-present)
```

```
  cq (build rel CommonInLocation
    object1 z
    object2 Europe)))

(describe (assert forall $u18
  forall $w18
  ant (build rel CommonInLocation
     object1 *u18
     object2 *w18)
  cq (build object *u18
    property common)))
```

4.19 Sentence 19.

Common types of carrots planted today include *Imperator, Nantes, Chantenay,* **and** *Danvers.*

4.19.1 Informal Discussion and/or Paraphrase.

Using the notion of a collective class of modern types of carrots introduced in the previous sentence might be appropriate here, but I think it would introduce an unnecessary complexity and may even be a case of going beyond the authors intention. We *presume* that "carrots planted today" are subclasses of the collective class of "modern types of carrots" but this is not necessarily the case—any of these four may be the same type of type of carrots planted in antiquity. Without more information we cannot rule out that possibility. Therefore the best representation is to identify each named type with its own subclass of carrot. SNePS allows us to say that these classes have properties, while first order logic forces us to say that the individual members of the classes have properties. In either case the members of these classes have the properties of being planted today and of being common. Following the lead of the previous sentence, we need to ask whether a property of simply being "common" actually captures the knowledge here. In the Sentence 18 it did not; those carrots were common with respect to a location, Europe. Here the carrots are actually common with respect to a time period. The period in which these carrots are common is "the present". Therefore we introduce a predicate CommonInPeriod to capture this aspect of the sentence. As above, a carrot that satisfies this predicate has the property of being "common" even though the meaning of this property is rather vague.

To capture the sense that the named subclasses of carrots are "included" in some overall set of classes planted today we can say that there exists a subclass of carrots consisting of all those carrots that are "planted today" and all the members of the four named subclasses are members of this class as well. The sense of the English word "include" suggests that there are more carrots in this class that are accounted for by the four named subclasses, but it really does not compel this interpretation. We can paraphrase the sentence as follows: *There are four subclasses of carrot: one called "Imperator", one called "Nantes", one called "Chantenay" and one called "Danvers". All the members of the four named subclasses are members of a subclass of carrots that consists of all carrots that are planted today and they all have the property that they are common at the present time.*

4.19.2 First-Order Logic Representation.

⟦`Imperator(x)`⟧ is the proposition that the individual x is a member of the class designated by the name "Imperator".

⟦`Nantes(x)`⟧ is the proposition that the individual x is a member of the class designated by the name "Nantes".

⟦`Chantenay(x)`⟧ is the proposition that the individual x is a member of the class designated by the name "Chantenay".

⟦`Danvers(x)`⟧ is the proposition that the individual x is a member of the class designated by the name "Danvers".

⟦`CommonInPeriod(x,y)`⟧ is the propostion that the individual x has the property of being common in the time period denoted by y.

⟦`CarrotPlantedToday(x)`⟧ is the proposition that the individual x is a member of the class of those carrots that are planted today.

FOL representation follows:

$$\begin{array}{lcl} \forall\ x\ \text{Imperator}(x) & & \\ \lor\ \text{Nantes}(x) & & \\ \lor\ \text{Chantenay}(x) & & \\ \lor\ \text{Danvers}(x) & \Rightarrow & \text{CarrotPlantedToday}(x) \\ & & \land\ \text{CommonInPeriod}(x,\text{the-present}) \end{array}$$

$$\forall\ y\ \text{CarrotPlantedToday}(y) \Rightarrow \text{Carrot}(y)$$

$$\forall\ z\ \text{CommonInPeriod}(z,\text{the-present}) \Rightarrow \text{HasProperty}(z,\text{common})$$

4.19.3 SNePS Interpretation.

```
(describe (assert forall $x19
  ant (build member *x19
     class Imperator)
  ant (build member *x19
     class Nantes)
  ant (build member *x19
     class Chantenay)
  ant (build member *x19
     class Danvers)
  cq (build min 2
    max 2
    arg (build member *x19
       class CarrotPlantedToday)
    arg (build rel CommonInPeriod
       object1 *x19
       object2 the-present))))

(describe (assert forall $y19
  ant (build member *y19
     class CarrotPlantedToday)
```

```
  cq (build member *y19
    class Carrot)))

(describe (assert forall $z19
  ant (build rel CommonInPeriod
     object1 *z19
     object2 the-present)
  cq (build object *z19
    property common)))
```

5 Conclusion.

The exercise of producing this paper has been highly instructive. When I selected the article on carrots I did so because I wanted something clear, straightforward and simple as the target of my first attempt at the craft of knowledge representation. The article does have those characteristics, but even so I have found myself frequently tracking down many blind alleys and discarding approaches that seemed promising before they were tested against reality. I am not completely happy with my efforts so far, but neither am I unhappy. I know that I have made a reasonable effort at the task and I have had reasonably good results. I would like to offer the following observations by way of conclusion:

- Many difficulties for a first order logic representation are presented by English quantifiers. Words such as “often” and “sometimes” are not easily represented in first order logic and since SNePS is at its foundation just an improved notation for first order logic the SNePS formalism gives no additional help. Continuum ideas, such as an extent of time, are also difficult.
- The knowledge “contained” in an article does not have existence independent of the reader of the article. The reader is expected to be an active participant in the communication with the author. Indeed, if the reader does not bring his or her experience and “common sense” to the communication in an active, interpretive fashion then the amount of knowledge communicated to the reader is significantly diminished.
- The author of the article assumes a certain common experience between himself and the reader. This is the “common sense” mentioned above. The actual text of the article does express a certain amount of knowledge explicitly, but a significant amount is *implicit.* The author relies on the reader to know certain things about the world, about the conventional and idiomatic use of language, and about what interpretations in an ambiguous set are reasonable. If this common experience is lacking the communication is again impaired.

Finally one more personal observation. This project was much, much more time consuming and difficult than I ever expected it to be. While in part this resulted from lack of experience, I am sure that the art and science of knowledge representation are far more difficult in an objective sense than would ever be anticipated by someone who had never tried to actually do it. My respect for those who have undertaken to make computers truly understand human language, and my awe at just how complex human language is, have been greatly increased.

6 REFERENCES.

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7 Appendix A – First Order Logic Terms and Predicates in Alphabetical Order.

⟦$1\frac{1}{2}$-feet⟧ is an individual representing a distance of $1\frac{1}{2}$ feet (Sentence 10).

⟦2-feet⟧ is an individual representing a distance of 2 feet (Sentence 10).

⟦about-100-days⟧ is an individual duration of about 100 days length (Sentence 14).

⟦Action-Occasion(x,y)⟧ is the proposition that the action represented by x occurs during the occasion represented by y (Sentence 9).

⟦after-antiquity⟧ is an intensional time period after that denoted by the English word "antiquity" (Sentence 18).

⟦Amount(x,y)⟧ is the proposition that the amount of substance x has magnitude y (Sentence 2).

⟦AncientGreek(x)⟧ is the proposition that the individual x is a member of the class of ancient Greeks (Sentence 16).

⟦AncientRoman(x)⟧ is the proposition that the individual x is a member of the class of ancient Romans (Sentence 16).

⟦Better(x,y)⟧ is the proposition that the individual x is better than the individual y (assuming only a single dimension for comparison exists) (Sentence 11).

⟦boiled⟧ is the property of being boiled.

⟦CanSurvive(x,y)⟧ is the proposition that the individual x can survive interaction with the individual y (Sentence 12).

⟦CanWithstand(x,y)⟧ is the proposition that the individual x can withstand interaction with the individual y (Sentence 12).

⟦carotene⟧ is the substance carotene (Sentence 3).

⟦Carrot(x)⟧ is the proposition that the individual x is a member of the class of actual carrots physically existing in the world (Sentence 1).

⟦Carrot-For-Coffee-Region(x)⟧ is the proposition that the individual x is a member of the class of Carrot-For-Coffee-Regions (Sentence 8).

⟦CarrotPlantedToday(x)⟧ is the proposition that the individual x is a member of the class of those carrots that are planted today (Sentence 19).

⟦Chantenay(x)⟧ is the proposition that the individual x is a member of the class designated by the name "Chantenay" (Sentence 19).

⟦Chop(x)⟧ is the action of chopping x (Sentence 9).

⟦coffee⟧ is the substance coffee (Sentence 8).

⟦common⟧ is the property of being common (Sentence 18).

⟦CommonInLocation(x,y)⟧ is the proportion that the individual x has the property of being common in the location denoted by y (Sentence 18).

⟦CommonInPeriod(x,y)⟧ is the proposition that the individual x has the property of being common in the time period denoted by y (Sentence 19).

⟦ConstituentOf(x,y)⟧ is the proposition that the individual x is a constituent of the collective individual y (Sentence 13).

⟦Contains(x,y)⟧ is the proposition that the individual x contains y (Sentence 2).

⟦CoolWinter(x)⟧ is that the individual x is a member of the class of cool-winters (Sentence 12).

⟦Crop(x)⟧ is the proposition that the individual x is a member of the class of crops (Sentence 13).

⟦Danvers(x)⟧ is the proposition that the individual x is a member of the class designated by the name "Danvers" (Sentence 19).

⟦Deep(x)⟧ is the proposition that the individual x has the property of being deep (Sentence 11).

⟦DevelopedInLocation(x,y)⟧ is the proposition that the individual x was developed in the location denoted by y (Sentence 18).

⟦DevelopedInPeriod(x,y)⟧ is the proposition that the individual x was developed during the period denoted by y (Sentence 18).

⟦Distance(x,y)⟧ is the proposition that the individual x is a distance (Sentence 10).

⟦eaten⟧ is the property of being eaten.

⟦Eats(x, y)⟧ is the proposition that the individual x eats the object denoted by y (Sentence 6).

⟦Eats-In(x, y, z)⟧ is the compound proposition that the individual x eats both the object denoted by y and the object denoted by z and that the object denoted by y is a component part of the object denoted by z (Sentence 6).

⟦Eats-With(x, y, z)⟧ is the proposition that the individual x eats both the object denoted by y and the object denoted by z (eats y together with z) (Sentence 6).

⟦Europe⟧ is the individual location denoted by the name "Europe" (Sentence 18).

⟦FallCrop(x)⟧ is the proposition that the individual x is a member of the class of fall-crops (Sentence 13).

⟦France⟧ is the individual location denoted by the name "France" (Sentence 18).

⟦Gardener(x)⟧ is the proposition that the individual x is a member of the class of gardeners (Sentence 13).

⟦GreaterThanOrEqualTo(x,y)⟧ is the proposition that the magnitude of the individual x is greater than or equal to the magnitude of the individual y (assuming only a single dimension for comparison exists) (Sentence 10).

⟦Grind(x)⟧ is the act of grinding x (Sentence 8).

⟦Grow(x,y)⟧ is the proposition that the individual x is grows (in the sense of "raises") the individual y (Sentence 16).

⟦GrowFrom(x,y)⟧ is the proposition that the individual x grows from the individual y (Sentence 10).

⟦GrowIn(x,y)⟧ is the proposition that the individual x grows in the individual y (Sentence 11).

⟦GrowToMaturity(x)⟧ is the action of x growing to maturity (Sentence 14).

⟦HasPart(x,y)⟧ is the proposition that the individual x has a part of itself which is the individual y; x is composed in part by y (Sentence 1).

⟦HasProperty(x,y)⟧ is the proposition that the individual x has a property represented by y (Sentence 1).

⟦HasRole(x,y)⟧ is the proposition that the individual x has a role (in an action) as a y (Sentence 1).

⟦Heat(x)⟧ is that the individual x is a member of the class of heats (Sentence 12).

⟦Human-Body(x)⟧ is the proposition that the individual x is a member of the class of human bodies (that is, x is a human body) (Sentence 4).

⟦Imperator(x)⟧ is the proposition that the individual x is a member of the class designated by the name "Imperator" (Sentence 19).

⟦Improve-Flavor(x)⟧ is the proposition that the flavor of x is improved (Sentence 9).

⟦In(x,y)⟧ is that the individual x is located in the region denoted by y (Sentence 8).

⟦iron⟧ is the substance iron (Sentence 5).

⟦lacy⟧ is the property of being lacy.

⟦Leaf(x)⟧ is the proposition that the individual x is a member of the class of leaves (Sentence 9).

⟦LessThanOrEqualTo(x,y)⟧ is the proposition that the magnitude of the individual x is less than or equal to the magnitude of the individual y (assuming only a single dimension for comparison exists) (Sentence 10).

⟦long⟧ is the property of being long.

⟦Make-Use(x)⟧ is the act of using x (Sentence 8).

⟦meats⟧ is a collective individual representing a specific collection of meats (Sentence 9).

⟦MedievalCarrot(x)⟧ is the proposition that the individual x is a member of the class of medieval carrots (Sentence 18).

⟦Mediterranean-region⟧ is the individual region identified by the phrase "the Mediterranean region" (Sentence 15).

⟦ModernTypeCarrot(x)⟧ is the proposition that the individual x is a member of the collective class of modern types of carrot (Sentence 18).

⟦much-heat⟧ is the property of having much heat (Sentence 12).

⟦Nantes(x)⟧ is the proposition that the individual x is a member of the class designated by the name "Nantes" (Sentence 19).

⟦NativeTo(x,y)⟧ is the proposition that the individual x is native to the individual region denoted by y (Sentence 15).

⟦northern-part-of-US⟧ is the region described by the phrase "the northern part of the United States" (Sentence 13).

⟦Nothing(x)⟧ is the proposition that the intensional individual x does not exist.

⟦Occasion(x)⟧ is the proposition that the individual x is an member of the class of all occasions existing throughout time (Sentence 9).

⟦OftenRaise(x,y)⟧ is the proposition that the individual x "often raises" a "thing" denoted by y (Sentence 13).

⟦orange⟧ is the color orange (Sentence 1).

⟦Perform-First-Act(x,y)⟧ is the proposition that the individual x performs action y as the first act in a possible sequence of actions (Sentence 8).

⟦Perform-Second-Act(x,y)⟧ is the proposition that the individual x performs action y as the second act in a possible sequence of actions (Sentence 8).

⟦Perform-Third-Act(x,y)⟧ is the proposition that the individual x performs action y as the third act in a possible sequence of actions (Sentence 8).

⟦Person(x)⟧ is the proposition that the individual x is a member of the class of persons (people) (Sentence 6).

⟦Plant(x)⟧ is the proposition that the individual x is a member of the class of actual plants existing in the world (Sentence 1).

⟦PlantedApart(x,y,z)⟧ is the proposition that the individuals x and y are planted a distance z apart from each other (Sentence 10).

⟦Purpose(x,y)⟧ is the proposition that the purpose of the action x is y (Sentence 9).

⟦RequiresToDo(x,y,z)⟧ is the proposition that the individual x requires individual y in order for x to perform action z (Sentence 14).

⟦Resembles(x,y)⟧ is the proposition that the individual x resembles the individual y (Sentence 18).

⟦Rich(x)⟧ is the proposition that the individual x has the property of being rich (Sentence 11).

⟦Roast(x)⟧ is the act of roasting x (Sentence 8).

⟦Root(x)⟧ is the proposition that the individual x is a root (Sentence 1).

⟦Salad(x)⟧ is the proposition that the individual x is a salad (Sentence 6).

⟦Seed(x)⟧ is the proposition that the individual x is a member of the class of seeds (Sentence 10).

⟦Soil(x)⟧ is that the individual x is a member of the class of soils (Sentence 11).

⟦Sprinkle-On(x,y)⟧ is the action of sprinkling x onto y (Sentence 9).

⟦Stem(x)⟧ is the proposition that the individual x is a member of the class of stems (Sentence 9).

⟦Substitute(x,y)⟧ is the proposition that the individual x substitutes for the individual y (Sentence 8).

⟦Substance(x,y)⟧ is the proposition that the individual x is a substance which is identified by the y (Sentence 2).

⟦sugar⟧ is the substance sugar (Sentence 5).

⟦SummerCrop(x)⟧ is the proposition that the individual x is a member of the class of summer-crops (Sentence 13).

⟦SummerHeat(x)⟧ is that the individual x is a member of the class of summer-heats (Sentence 12).

⟦the-1200's⟧ is the individual time period denoted by the English phrase "the 1200's", corresponding to the thirteenth century of the common era (a sub-period of the medieval period) (Sentence 18).

⟦the-present⟧ is the individual time period denoted by the English phrase "the present", that is, the period in which modern types of carrots grow (Sentence 18).

⟦thick⟧ is the property of being thick.

⟦thin⟧ is the property of being thin.

⟦TimeRange(x,y)⟧ is an individual time period which begins with the period x and extends continuously through the period y (Sentence 18).

⟦TinySeed(x)⟧ is the proposition that the individual x is a member of the class of tiny-seeds (Sentence 10).

⟦tough⟧ is the property of being tough.

⟦TypicalCarrot(x)⟧ is the proposition that the individual x is a member of the class of intensional entities representing typical carrots (Sentence 1).

⟦UseAsMedicine(x)⟧ is the purpose of using x as medicine (Sentence 17).

⟦UseAsFood(x)⟧ is the purpose of using x as food (Sentence 17).

⟦Uses(x,y)⟧ is the proposition that the individual x uses the individual y (Sentence 4).

⟦Vitamin(x)⟧ is the proposition that the individual x is a member of the class of vitamins (Sentence 2).

⟦vitamin-A⟧ is the vitamin named vitamin A (Sentence 4).

⟦vitamin-B1⟧ is the vitamin named vitamin B_1 (Sentence 2).

⟦vitamin-B2⟧ is the vitamin named vitamin B_2 (Sentence 2).

⟦vitamin-C⟧ is the vitamin named vitamin C (Sentence 2).

⟦Winter(x)⟧ is that the individual x is a member of the class of winters (Sentence 12).

⟦world⟧ is the world (geographically speaking) (Sentence 8).

8 Appendix B – SNePS session loading the SNePSUL commands in this paper.

The following seven pages (available only in the hardcopy version of this document) are a script of a SNePS session in which the SNePSUL commands (the "SNePS Interpretation" sections) given in the text were actually executed. These have been printed in a reduced format to save space.