

# 10

## Frames and Commonsense

In Chapter 9, you learned how frames can capture the properties of individuals and events. In this chapter, you learn how frames can capture detailed knowledge about how acts happen.

First, you learn about how *thematic-role frames* describe the action conveyed by the verbs and nouns appearing in typical declarative sentences. Next, you learn how *action frames*, *state-change frames*, *subaction links* and *result links* describe what happens on a deeper, syntax-independent level that is more suited to question answering, sentence paraphrasing, and language translating.

Once you have finished this chapter, you will understand that frames make it possible to capture and exploit some of the knowledge carried, both explicitly and implicitly, by human language.

### THEMATIC-ROLE FRAMES

Much of what happens in the world involves actions, and objects undergoing change. It is natural, therefore, that many of the sentences in human language amount to descriptions that specify actions, identify the object undergoing change, and indicate which other objects are involved in the change. In this section, you learn about one representation for that kind of knowledge, you learn how to build descriptions using that representation, and you learn how to use those descriptions to answer questions.

### An Object's Thematic Role Specifies the Object's Relation to an Action

In linguistic terms, verbs often specify actions, and noun phrases identify the objects that participate in the action. Each noun phrase's **thematic role** specifies how the object participates in the action. You speak, for example, of the *agent*, *thematic object*, and *instrument* thematic roles.<sup>†</sup>

The sentence, "Robbie hit a ball with a racket," for example, carries information about how Robbie, a ball, and a racket relate to the verb *hit*. A procedure that understands such a sentence must discover that Robbie is the **agent** because he performs the action of hitting, that the ball is the **thematic object** because it is the object hit, and that the racket is the **instrument** because it is the tool with which hitting is done.

Thus, sentence analysis requires, in part, the answers to these questions:

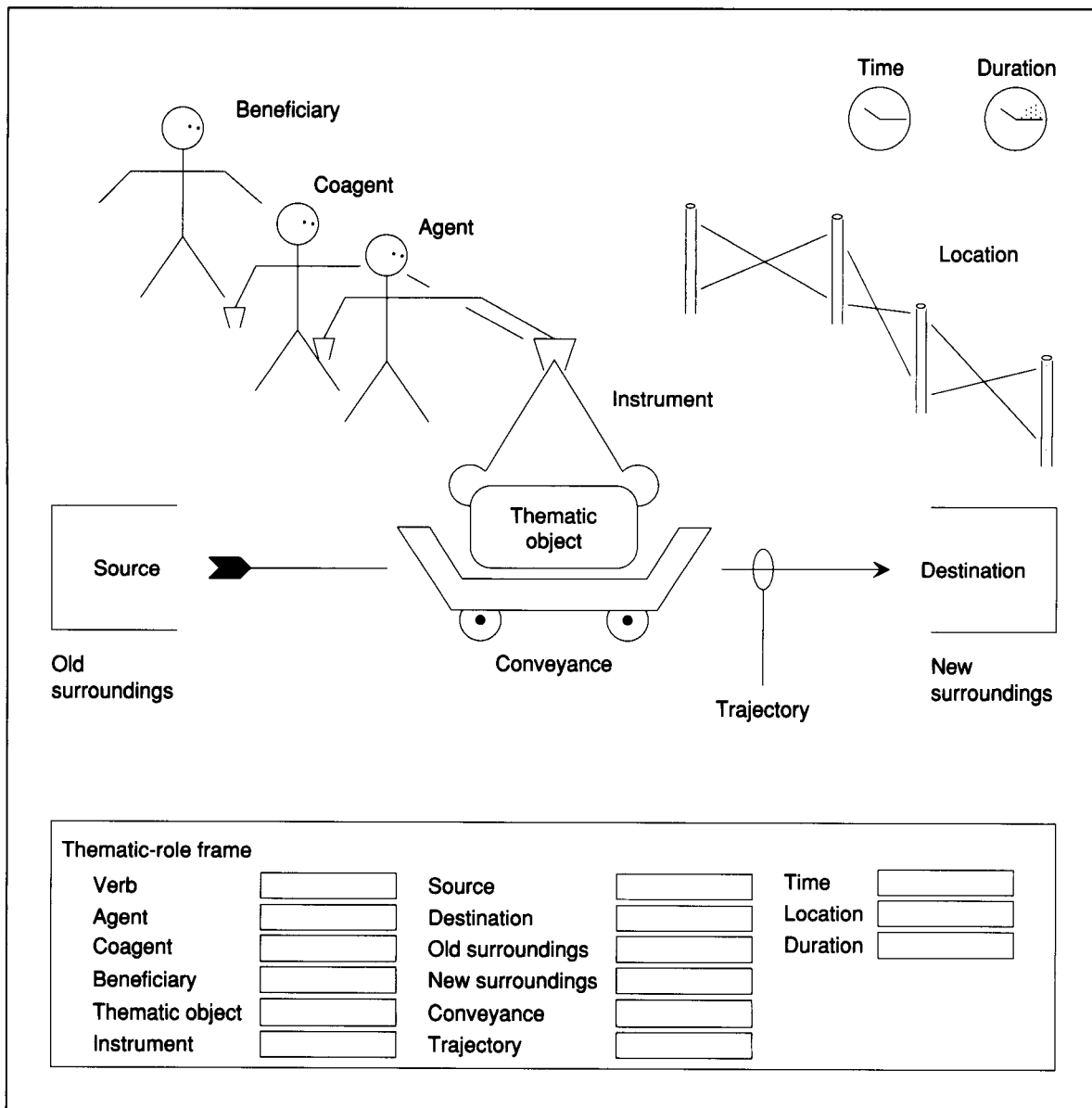
- What thematic roles are to be filled by a sentence?
- How is it possible to determine the thematic roles of the noun phrases in a sentence?

The number of thematic roles embraced by various theories varies considerably. Some people use a half-dozen thematic roles. Others use three or four times as many. The exact number does not matter much, as long as it is great enough to expose natural constraints on how verbs and thematic-role instances form sentences.

For illustration, let us confine ourselves to a world for which the thematic roles shown in figure 10.1 are adequate.

- **Agent.** The agent causes the action to occur. Volition is generally implied, as in "*Robbie* hit the ball," but there are exceptions: "*The moon* eclipsed the sun." The agent is often the surface subject, but in a passive sentence, the agent also may appear in a prepositional phrase: "The ball was hit *by Robbie*."
- **Coagent.** The word *with* may introduce a noun phrase that serves as a partner to the principal agent. The two carry out the action together: "Robbie played tennis *with Suzie*."
- **Beneficiary.** The beneficiary is the person for whom an action is performed: "Robbie bought the balls *for Suzie*."
- **Thematic object.** The thematic object is the object the sentence is really all about—typically the object undergoing a change. Often, the thematic object is the same as the syntactic direct object, as in "Robbie hit *the ball*." On the other hand, in a passive sentence, the thematic object appears as the syntactic subject as in "*The ball* was hit by Robbie."

<sup>†</sup>Using the term *thematic object*, instead of just the term *object*, avoids confusion with the syntactic direct and indirect objects. Some people avoid the word *object* altogether, calling the thematic object the *patient*.



**Figure 10.1**

Thematic roles focus on how noun phrases relate to actions.

- **Instrument.** The instrument is a tool used by the agent. The preposition *with* typically introduces instrument noun phrases: "Robbie hit a ball *with a racket*."
- **Source and destination.** Changes are often simple changes in physical position. The source is the initial position, and the destination is the final position: "Robbie went *from the dining room to the kitchen*."

- **Old surroundings and new surroundings.** The old surroundings is the location out of which something comes, and the new surroundings is the location in which it goes: “Robbie took the cereal out *of the box* and put it *into the bowl*.”
- **Conveyance.** The conveyance is something in which or on which one travels: “Robbie always goes *by train*.”
- **Trajectory.** Motion from source to destination takes place over a trajectory. In contrast to the other role possibilities, several prepositions can serve to introduce trajectory noun phrases: “Robbie and Suzie went in *through the front door*; he carried her *over the threshold*.”
- **Location.** The location is where an action occurs. As in the trajectory role, several prepositions are possible, each of which conveys meaning in addition to serving as a signal that a location noun phrase is coming: “Robbie and Suzie studied *in the library, at a desk, by the wall, under a picture, near the door*.”
- **Time.** Time specifies when an action occurs. Prepositions such as *at, before, and after* introduce noun phrases serving as time role fillers. “Robbie and Susie left *before noon*.”
- **Duration.** Duration specifies how long an action takes. Prepositions such as *for* indicate duration. “Robbie and Susie jogged *for an hour*.”

Another way of summarizing all this information about thematic roles is to use the representation specification form, noting that all the thematic roles involved in a particular action can be viewed as slot values for a thematic-role frame:

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A **thematic-role system** is a representation

That is a frame system

In which

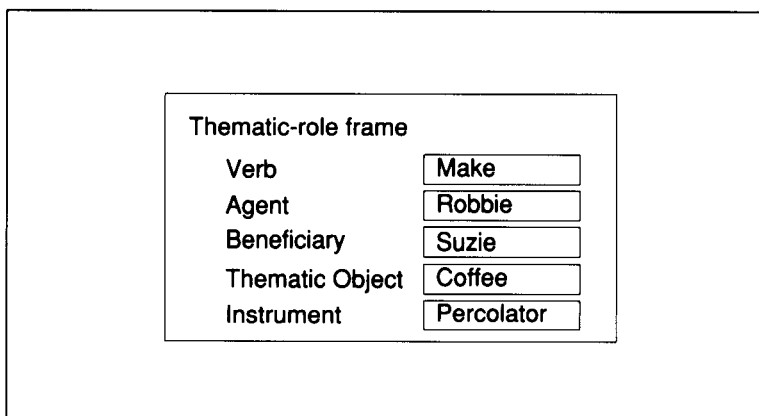
- ▷ The slots are, typically, *verb, agent, coagent, beneficiary, thematic object, instrument, source, destination, old surroundings, new surroundings, conveyance, trajectory, time, location, and duration*.
  - ▷ Each frame describes an action. The verb slot identifies the action. Other slots identify objects that play various roles with respect to the action.
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### Filled Thematic Roles Help You to Answer Questions

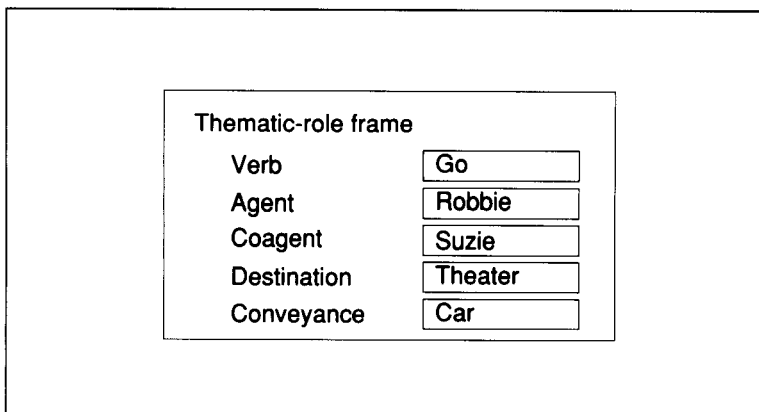
Because thematic-role frames make certain roles explicit, many questions are easy to answer once values for thematic-role slots are worked out. Consider this sentence:

*Robbie made coffee for Suzie with a percolator.*

**Figure 10.2** A filled thematic-role frame. The slot values provide answers to a variety of questions about what happened.



**Figure 10.3** Another filled thematic-role frame. Again, the slot values provide answers to a variety of questions about what happened.



There are four noun phrases, each of which fits into a particular role, as shown in figure 10.2. Four corresponding questions can be answered:

<i>What</i> was made?	→	thematic object	→	coffee
<i>Who</i> made it?	→	agent	→	Robbie
<i>With what</i> was it made?	→	instrument	→	a percolator
<i>For whom</i> was it made?	→	beneficiary	→	Suzie

Similar results follow from another sentence:

*Robbie went to the theater with Suzie by car.*

Again there are four noun phrases, each of which fits into a particular role, as shown in figure 10.3.

<i>Who</i> went?	→	agent	→	Robbie
<i>With whom</i> did he go?	→	coagent	→	Suzie
<i>To where</i> did he go?	→	destination	→	the theater
<i>By what means</i> did they travel?	→	conveyance	→	car

Thus, thematic roles roughly correspond to some of the simple questions about actions.

Although such question answering is important, you must keep in mind that it is only one of the functions of front-line semantic analysis. Presumably, the results of thematic-role identification are the fodder for still deeper mechanisms that understand the relations among individual sentences, evolving contexts, and global knowledge about the world.

### Various Constraints Establish Thematic Roles

Of course, slot values have to be ferreted out by a language-understanding program before they can support question analysis. Fortunately, for simple English sentences, many constraints help you to establish the thematic role of any given noun phrase:

- Each verb carries strong preferences about what thematic roles can appear and where the noun phrases that fill those thematic roles can be placed, relative to the verb.
- Prepositions limit a noun phrase's role possibilities.

Here is the relation between prepositions and role possibilities:

Preposition	Allowable thematic role
by	agent or conveyance or location
with	coagent or instrument
for	beneficiary or duration
from	source
to	destination

Thus, the preposition *by* signals that you can expect an agent, a conveyance, or a location, but not a coagent, beneficiary, instrument, source, or destination.

- The noun itself may limit possible role identifications.

For example, you get a different picture from “Robbie was sent to the scrap heap by parcel post,” than from “Robbie was sent to the scrap heap by Marcel Proust,” because parcel post is more likely to be a conveyance, whereas Marcel Proust is more likely to be an agent.

- Only one filler is allowed in any sentence for most thematic roles.

If, somehow, the thematic role of one noun phrase is determined, then the other noun phrases in the sentence are forced to fill other thematic roles.

Note, however, that a filler may involve more than one object if the objects are conjoined explicitly by *and*. In “Robbie ate with a fork with a gazerkle,” it is not clear whether the gazerkle is a coagent, because **gazerkle** is a made-up word. It is clear, however, that the gazerkle is not an instrument because the fork has a lock on that. On the other hand, if the sentence were, “Robbie ate with a fork and a gazerkle,” the fork and gazerkle would

fill the instrument thematic role together, and hearing such a sentence, you would learn that a gazerkle can be an instrument.

Time, trajectory, and location are exceptions to the one-filler rule because more than one noun phrase may be involved in their description. It is perfectly reasonable to say, for example, “Robbie ate at noon on Monday.”

### A Variety of Constraints Help Establish Verb Meanings

Verbs and verb phrases in isolation exhibit meaning ambiguity just as noun phrases exhibit thematic-role ambiguity. Conveniently, meaning-selection constraints often seem to resolve the ambiguity.

The noun phrase in the thematic-object thematic role can help considerably. Consider the following examples:

*He shot the rabbit.*

*He shot the picture.*

Shooting a rifle and shooting a camera are very different kinds of shooting, even though there are similarities at a certain level of abstraction. The words *rifle* and *camera* are not specifically mentioned; information found in the words *rabbit* and *picture* is apparently enough to guide your interpretation toward one meaning or the other.

Another way verb meanings are selected is through a small family of words called **particles**. For example, see how particles select meanings for *throw* and *pick*:

*He threw some food.*

*He threw away some food.*

*He threw up some food.*

*She picked up some candy.*

*She picked out a nice assortment.*

One other strong influence on meaning derives from the overall context. Curiously, quite a lot can be gained from a very coarse categorization of life's subjects into a few worlds:

#### ■ The physical world.

Objects change position, and they acquire and lose various properties and relations to other objects. Other worlds seem to relate to the physical world through analogy.

#### ■ The mental world.

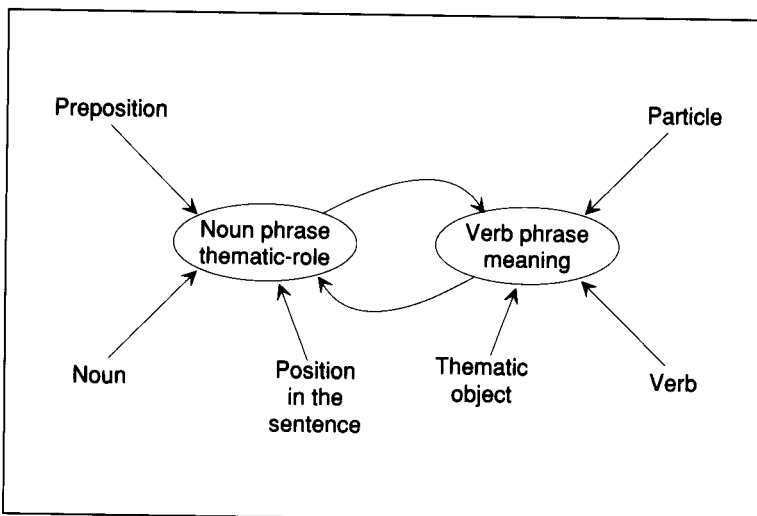
The objects in the mental world are facts, ideas, and concepts. You sometimes think about them with actions, properties, and relations borrowed from the physical world, just as though the abstractions were physical things. Consider these examples:

*The theory is supported by facts.*

*The overall concept is solid.*

*The idea was exposed in the class.*

**Figure 10.4** Many constraints help determine noun-phrase thematic roles and verb-phrase meanings. Among the noun phrases, the one in the thematic object role has a strong influence on verb meaning.



#### ■ The ownership world.

In the ownership world, the objects are abstract certificates of control, possession, or ownership, whose locations are in the hands of people or organizations. Again, the events in this world often are communicated in language that is analogous to that of the physical world:

*Robbie took the ball away from Bozo.*

*The bank took the house back.*

Note that transfer of a physical thing is not necessarily implied. Robbie is probably holding the ball he took control of, but the bank probably never moves a physical house.

#### Constraints Enable Sentence Analysis

As suggested in figure 10.4, many constraints help you to assign thematic roles to the noun phrases in simple sentences. To see how they do so, you need to agree to a few assumptions.

First, assume you have a dictionary of stored information about nouns and verbs. Also, assume, for the sake of simplicity, that all noun phrases help you to describe the action; no noun phrase helps you to describe another noun phrase.

Of course, in addition to determining noun-phrase thematic roles, you also need to determine the verb phrase's meaning. Several constraints enable you to hack away at the potential meanings, ultimately determining a unique interpretation, or, at worst, a small number of interpretations. Noting the presence of a particle helps you considerably. You can instantly throw out verb meanings that are inconsistent with an observed particle, or that are inconsistent with the absence of a particle.



If you wish to determine the noun-phrase thematic roles, the first step is to locate the thematic object among the noun phrases without prepositions. If the verb phrase is passive, then the thematic object—the thing the sentence is about—must occupy a spot in front of the verb. It is what you learned in grammar school to call the **syntactic subject**.

If the verb is active, then the thematic object follows the verb. If there is only one noun phrase after the verb, possibly accompanied by one or more prepositional phrases, then that noun phrase is the thematic object. In the rest of this chapter, such noun phrases are called **preposition-free noun phrases** to distinguish them from noun phrases that are part of larger prepositional phrases.

If there are two preposition-free noun phrases following the verb, then the second is the thematic object, as long as the verb requires a thematic object. Assume that it does, constraining sentence construction, just to keep illustrative analysis manageable.

With the thematic object in hand, there is an opportunity to weed out unlikely verb meanings—namely, those whose stored meanings are incompatible with the thematic object.

At this point, it is conceivable that more than one verb meaning remains. Accordingly, you must carry more than one interpretation forward in parallel. Fortunately, in human communication, as the number of interpretations seems about to explode, some powerful constraint appears to keep the number of interpretations small. Note, incidentally, that strength in one dimension allows flexibility in another. It is easy to imagine how a language might have a larger number of prepositions than English has, with an offsetting reduction in word-order constraint. Finnish is an example of such a language.

Now you can nail down the thematic roles for other noun phrases, starting with those without prepositions. Again, the surviving verb meanings may state preferences about what is needed and where what is needed can be found. Many active verbs, for example, demand an explicit agent and prefer to find that agent in the syntactic subject position. Such verb-carried demands are ordinarily sufficient to fix the role for the one or two preposition-free noun phrases that may be found in addition to the thematic object. Knowing the roles for the preposition-free noun phrases greatly simplifies the analysis of other noun phrases, because those other noun phrases cannot be assigned to thematic roles that are already spoken for.

Consider, for example, a sentence containing a noun phrase introduced by the word *by*. This word typically introduces either the agent role or the conveyance or the location. If you have already determined that agent role is spoken for by the syntactic subject, then only the conveyance and location possibilities remain. Generally, you can resolve this remaining ambiguity either by using knowledge about the words in the noun phrase or by deferring to the dictionary-stated needs of the verb.

Finally, once the thematic roles are known for all noun phrases, certain roles may be present that help you to resolve remaining verb-meaning ambiguity.

Whew! It is time to capture all these steps by restating them in procedural English:

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To determine thematic roles,

- ▷ Obtain possible verb meanings from the dictionary. Throw away those verb meanings that are inconsistent with the verb's particle, if there are any.
  - ▷ Find the thematic object among the preposition-free noun phrases.
  - ▷ Throw away the verb meanings that the dictionary says are inconsistent with the thematic object.
  - ▷ For each remaining noun phrase, determine the thematic role.
  - ▷ Throw away the verb meanings that the dictionary says are inconsistent with the observed thematic roles.
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Although there are more complicated procedures, the one introduced here is powerful enough to handle the forthcoming examples.

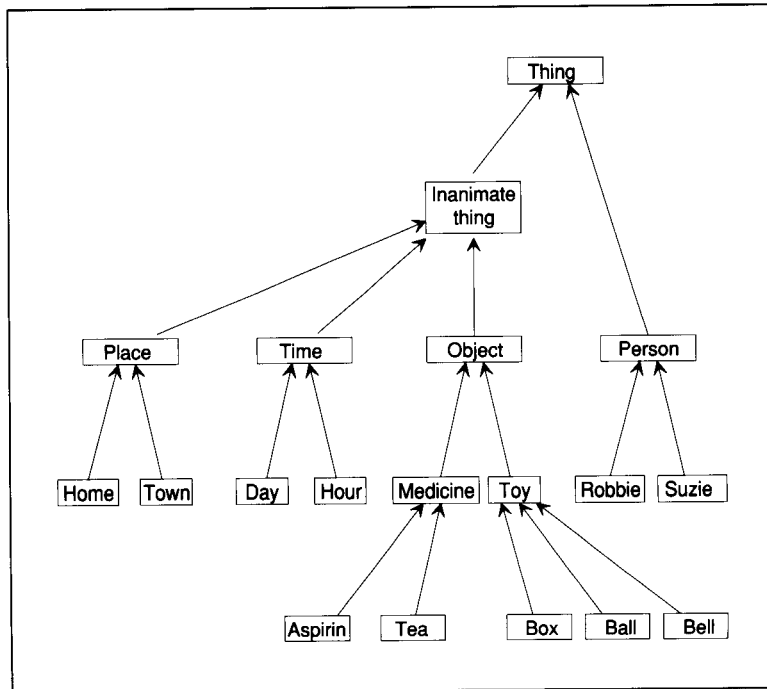
### Examples Using Take Illustrate How Constraints Interact

Suppose Robbie and Suzie communicate using a simple subset of English. To keep the illustration simple, they talk only about the things shown in figure 10.5. The verbs may have more than one meaning, but they certainly do not have all of the meanings possible in unrestricted English.

Robbie and Suzie move objects, get sick, engage in business activities, and date. Consequently, the verb *take* has a variety of meanings:

- *Take1* means transport. Either a source or a destination or both should appear.
- *Take2* means swindle. The source and destination roles are absent when this meaning is intended. Only people can be swindled.
- *Take3* means to swallow medicine. The available medicines include aspirin. The beneficiary is the same as the agent.
- *Take4* means to steal. People are not stolen.
- *Take5* means to initiate and execute a social event with another person. The particle *out* is always used.
- *Take6* means to remove. The particle *out* is always used. People cannot be removed.
- *Take7* means to assume control. The particle *over* signals this meaning.
- *Take8* means to remove from the body. The particle *off* is always used.

**Figure 10.5** A small world used to illustrate the effect of various sentence constraints.



These various meanings of *take* combine with noun phrases according to the thematic-role constraints you have been studying. Assume all passive sentences have exactly one preposition-free noun phrase, the syntactic subject, and that preposition-free noun phrase appears before the verb. Also assume that thematic roles are subject to the constraints given in the following table:

Thematic role	Preposition	Allowed class
agent	by	person
coagent	with	person
beneficiary	for	person
thematic object	—	—
instrument	with	inanimate
source	from	—
destination	to	—
old surroundings	out of	inanimate
new surroundings	into	inanimate
conveyance	by	inanimate
duration	for	a time

Now you can examine a few sentences with a view toward better understanding the way various constraints interact.

*Robbie took aspirin.*

The verb meanings *Take5* through *Take8* are eliminated, because there is no particle. Evidently Robbie is the agent and aspirin is the thematic object by virtue of word order and the lack of alternatives. *Take1* is unlikely, because there are no noun phrases that can be either the source or the destination of a transporting action. *Take2* is out, because aspirin is not a subclass of people and hence cannot be swindled. Thus, the sentence means that Robbie either swallowed or stole aspirin.

*Robbie took aspirin for Suzie.*

Robbie is the agent and aspirin is the thematic object by the same word-order argument used before. Again only *Take3* and *Take4* survive particle and thematic object considerations. *For* can flag either the beneficiary or duration, but because Suzie is not time, she must be the beneficiary. This observation, in turn, eliminates the *Take3* interpretation—swallowing medicine—because swallowing medicine requires the agent and beneficiary to be the same. Robbie has stolen. Of course, Robbie may have swallowed aspirin because Suzie begged and pleaded with him to do so, but that conclusion is incompatible with our assumptions here.

*Robbie took out Suzie.*

The particle limits the verb meaning to *Take5* and *Take6*, to date or to remove. *Take6* requires an inanimate thematic object, so Robbie dated Suzie.

*Robbie took out the box.*

A box is inanimate; hence it is removed, not dated.

*Robbie took the ball to Suzie.*

The ball is the thematic object, so *Take1*, to transport, and *Take4*, to steal, are the alternatives. Because a destination is given, *Take1* is preferred.

*Robbie took Suzie.*

Suzie being the thematic object, *Take1* and *Take2*, to transport and to swindle, are possible. Because there is no source or destination, Robbie has probably swindled Suzie.

*Robbie took Suzie to town.*

With a destination, the swindle conclusion is unlikely. Robbie has transported Suzie.

*The bell was taken out of town by Robbie by car for a day for Suzie.*

Because the sentence is passive, the bell is the thematic object. Because a bell is both inanimate and not a medicine, the verb meaning must be *Take1* or *Take4*. The compound preposition *out of* can flag old surroundings. Knowing that a town is a place and places are possible old surroundings resolves the ambiguity in favor of *Take1*. *Car* is an unknown word, so it could be either the agent or a conveyance. But because Robbie is animate,

he must be an agent, thus filling the agent role, forcing the car to be a conveyance. Finally, *Suzie* and *day* are easily resolved into beneficiary and duration, because Suzie cannot be a time and a day cannot be a beneficiary.

## EXPANSION INTO PRIMITIVE ACTIONS

In the previous section, you learned how thematic-role frames deal with the verbs and nouns in sentences. In this section, you learn how to go underneath the words, searching for more meaning. Here are some examples of what your search enables you to do:

- You can guess what happens when an action is taken. You can guess, for example, that comforting someone probably implies that the person emotional state improves.
- You can guess the details of how an action is done. You can know, for example, that eating probably involves moving a fork or a spoon, requiring the movement of a hand.

## Primitive Actions Describe Many Higher-Level Actions

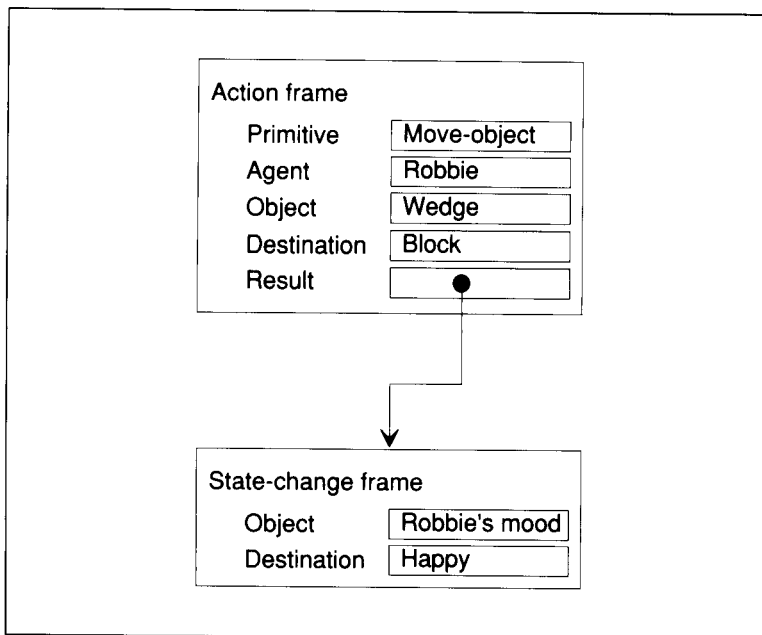
How many primitives are needed to describe the actions denoted by English verbs? The answer may be a surprisingly small number. It seems that many ordinary verbs are used as a sort of shorthand for ideas that can be expressed as well by combinations of basic primitives and default slot fillers. The combination process, called **telescoping**, accounts for an amazing number of superficially distinct verbs.

During the 1930s, champions of **Basic English** as a world language argued persuasively that people can get by with a vocabulary of only 1000 words by depending heavily on *come*, *get*, *give*, *go*, *keep*, *let*, *make*, *put*, *take*, *have*, *say*, *see*, and *send*. In Basic English, the verb *eat*, for example, is translated, from the thematic-role perspective, into *put*, together with a new surroundings thematic role prefilled with something such as the eater's stomach. Indeed, the eater's stomach is so much a part of the definition of *eat* that it seems strange to have it mentioned explicitly: one does not say, "I am eating a sandwich *into my stomach*."

The following list of primitives is similar to the list in Basic English, but it was originally constructed for the benefit of computer programs, rather than for human communication. The list includes actions in the physical world, the mental world, and the ownership world:

Move-body-part	Move-object
Expel	Ingest
Propel	Speak
See	Hear
Smell	Feel
Move-possession	Move-concept
Think-about	Conclude

**Figure 10.6** Much of the meaning of simple sentences is captured by Action frames and State-change frames tied together through Result slots. Here putting a wedge on a red block makes Robbie happy.



A variety of examples in the rest of this section show how these primitives help you to capture the meaning of simple sentences.

### **Actions Often Imply Implicit State Changes and Cause-Effect Relations**

Many sentences are about a primitive action connected to a state change by a Result link. Consider this sentence:

*Robbie enjoyed putting the wedge on the red block.*

Evidently, the action caused Robbie to be in the state of being happy. Nothing is known about how he felt before he moved the block, but while he moved it, he was happy. It is convenient to represent such sentences as combinations of Action frames and State-change frames. Figure 10.6, for example, pictures what happens when Robbie puts the wedge onto the red block. Note the Result link; it indicates that the action causes the state change.

Of course, one action also can cause another action. You indicate this relation by placing a Result link between the two things involved. Consider this sentence, for example:

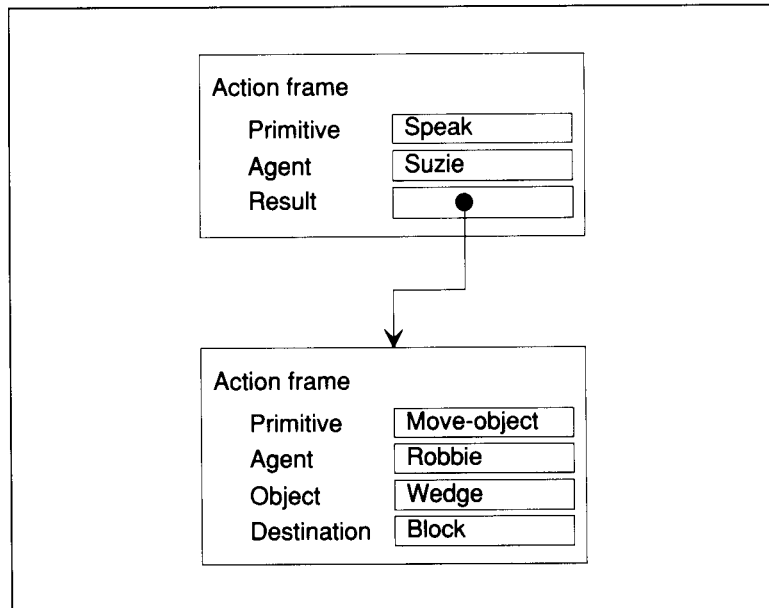
*Suzie told Robbie to put the wedge on the red block.*

For this sentence, the diagram of figure 10.7 is appropriate.

Some sentences announce only state changes, leaving the actions that cause the state changes unspecified. Suppose someone says this:

*Suzie comforted Robbie.*

**Figure 10.7** One action can cause another as when Suzie tells Robbie to do something.



There is a state change because Robbie is less sad than he was, assuming *comfort* implies original sadness. But what exactly did Suzie do? She caused Robbie to be less sad, certainly, but by what action? Did she talk with him, take him for a walk, or just help him move the wedge? There is no way of knowing from the sentence, so all that can be done is to represent what is known, as shown in figure 10.8. Note the use of the maximally nonspecific *Do* in the Primitive slot.

Let us look at one more example showing how actions and state changes can interdigitate:

*Robbie was gored by the test.*

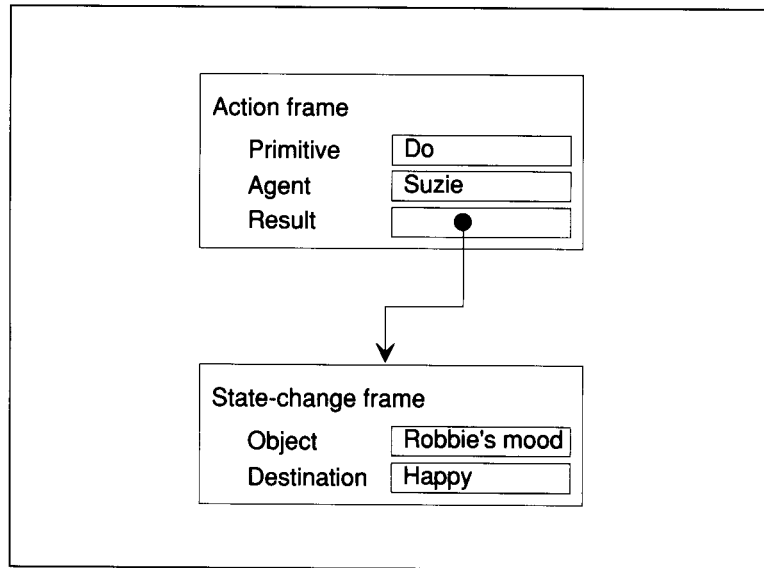
This language is metaphoric. The test itself presumably did no damage to poor Robbie; it was getting a bad grade that hurt him. Moreover, no one stuck a horn in his gut; something merely made him feel as though a horn had been thrust into him.

The real idea conveyed, when stripped of the color, is represented in figure 10.9. Note that *Do* is used because it is hard to guess precisely what Robbie did or perhaps failed to do. Overall, the example again demonstrates that a sentence's verb may imply a state-change rather than an action.

### Actions Often Imply Subactions

The Subaction slot is used to indicate that an action involves one or more subactions. Through Subaction slots, actions reveal their pieces, and then the pieces themselves reveal their pieces, ad nauseum.

**Figure 10.8** Some sentences specify only state change even though they seem to be about actions. Saying “Suzie comforted Robbie” gives no clue about how Robbie’s improved state is achieved.



Putting a wedge on a red block involves a Move-object action with three Move-body-part subactions, as indicated in figure 10.10. Moving the hand employs one Move-body-part, whereas grasping and ungrasping employ two others, each dealing with finger movements.

As another example, suppose that Robbie eats some ice cream. Figure 10.11 shows how the basic action, Ingest, calls to mind a Move-object involving a spoon. Of course, there is no way of knowing that Robbie eats the ice cream with a spoon, given only “Robbie eats ice cream.” He may eat an ice-cream cone or drink a milk shake. Using a spoon is only a default presumption, a general image called up if explanation is demanded and nothing specific to the situation is known.

### Primitive-Action Frames and State-Change Frames Facilitate Question Answering and Paraphrase Recognition

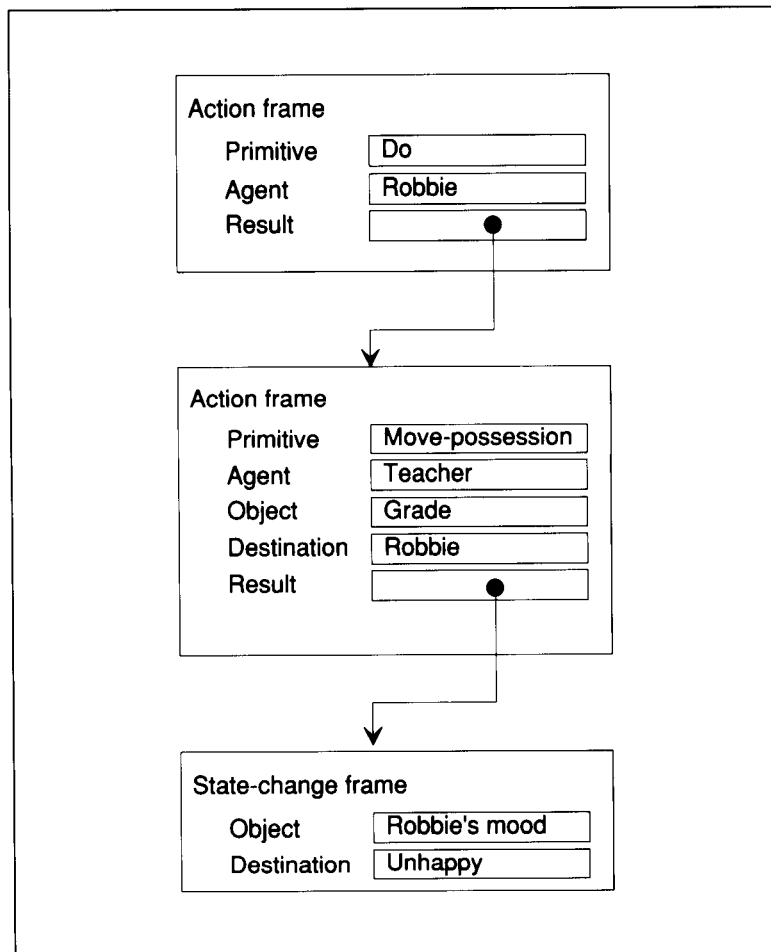
Like thematic-role frames, primitive-action frames and state-change frames make it possible to answer certain questions directly. Here are some examples:

- How is an action done? Answer by expanding the action into primitive actions and state changes. Give more detail by working through Subaction slots.

For example, Robbie eats ice cream by ingesting it (indicated by Ingest). He ingests it by moving a spoon (indicated by Move-object). He moves the spoon by moving his hand (indicated by Move-body-part).



**Figure 10.9** Considerable knowledge may be needed to expand simple-sounding metaphors into an arrangement of primitive-action and state-change frames. The diagram here represents a statement that Robbie was gored by a test.

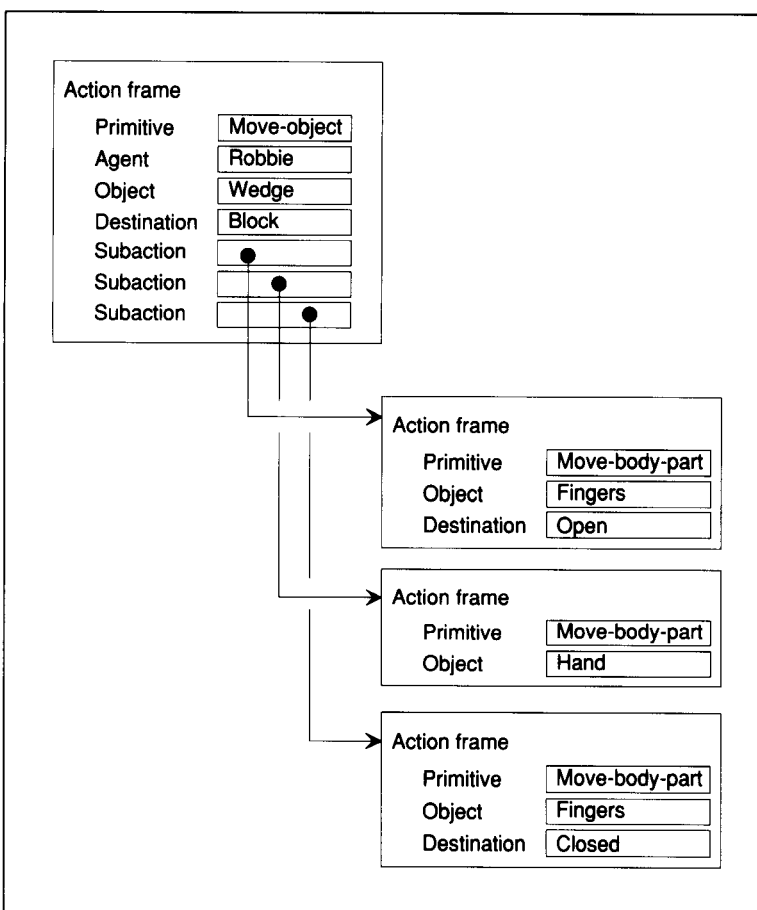


- What will happen if an action is done? Answer by first expanding the action into primitive-action and state-change frames. Then you may be able to find a similar, but more complete expansion in a database of remembered precedents.

For example, if Suzie hits Robbie (by Move-body-part her fist to his body), a remembered precedent may indicate, via a Result link, that he is likely either to hit her back (by Move-body-part his fist to her body) or to cry (by Expel tears). A remembered precedent, consisting of tightly coupled, expectation-suggesting primitive-action and state-change frames, is called a **script**.

- Does one sentence have the same meaning as another? Answer by expanding both into primitives and checking to see whether the results match.

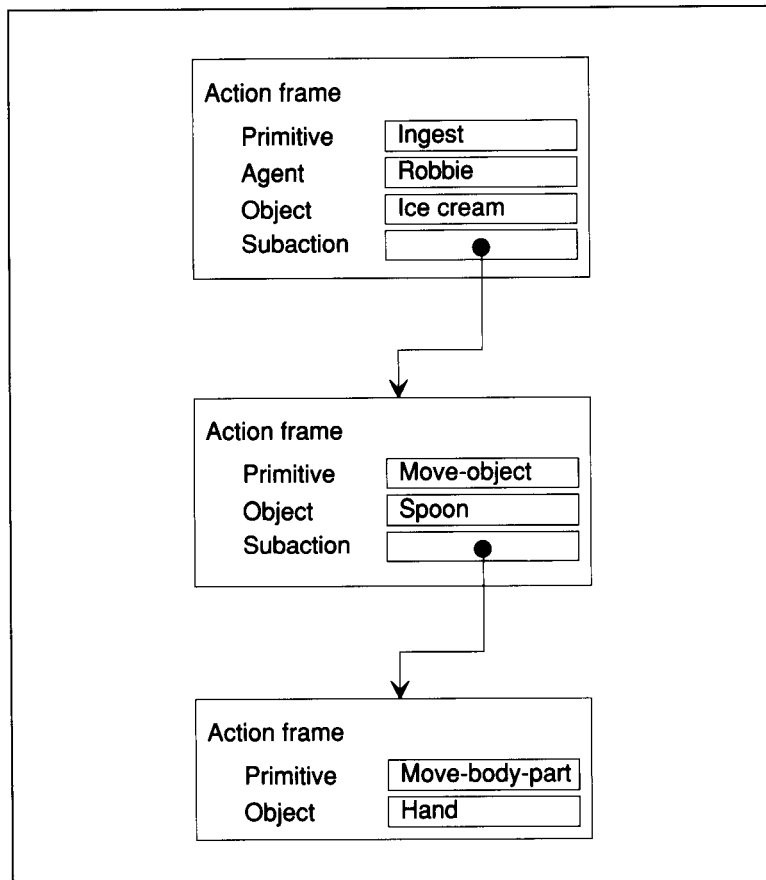
**Figure 10.10** Subaction slots offer another way of tying together action frames. This simple arrangement shows that moving a wedge is ultimately accomplished by a sequence of Move-body-part primitives.



For example, “Suzie comforted Robbie” has the same meaning as “Suzie did something to make Robbie happy,” because both expand into an action frame with an unspecified action and a state-change frame with Robbie’s mood improving. Evidently, the sentences are paraphrases of each other.

The assumption behind the paraphrase test is that sentences have the same meaning if and only if they expand into the same primitive-action and state-change frames—a gigantic, heavily contested assumption. Some people deny that primitive-action and state-change frames are good canonical forms for describing the meanings of sentences. Other people contend that even if primitive-action and state-change frames do qualify as a good canonical form, there is still no reason to believe that there is a procedure that will transform sentences with the same meaning into the same primitive-action and state-change descriptions. Still other people do not care, arguing that paraphrase recognition is only a small, rather insignificant part of commonsense reasoning.

**Figure 10.11** In this example, Robbie eats ice cream by moving a spoon to the mouth.



### Thematic-Role Frames and Primitive-Action Frames Have Complementary Foci

You have seen that primitive-action and state-change frames make explicit certain action-describing details:

- The primitive actions in Primitive slots make explicit what actions occur.
- The slot values in state-change frames make explicit what state changes occur.
- The frames in Result and Subaction slots make explicit what consequences and methods are assumed.

Note that primitive-action and state-change frames complement thematic-role frames with respect to what is made explicit. The specification of thematic-role frames, as given, places no constraint on the values allowed in the verb slot, but the specification makes a fuss over the names of the other slots. In contrast, in a specification for a primitive-action and state-

change system, the emphasis is on Subaction and Result slots and on the vocabulary of values allowed in the Primitive slot; everything else is loose:

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A **primitive action system** is a representation

That is a frame system

In which

- ▷ Action frames contain a Primitive slot that must be filled by a value drawn from a small, canonical set, such as Move-body-part, Move-object, Expel, Ingest, Propel, Speak, See, Hear, Smell, Feel, Move-possession, Move-concept, Think-about, Conclude, and Do.
  - ▷ State-change frames contain an Object slot that is filled with an application-specific object or quantity.
  - ▷ An Action frame may be connected to one or more other Action frames via a Subaction slot.
  - ▷ Action frame and State-change frames may be connected to each other via Result slots.
  - ▷ Other slots and slot values are application specific.
- 

## SUMMARY

- A thematic-role frame is an action-oriented representation focused on identifying the roles played by various objects.
- Primitive-action frames and state-change frames constitute an action-oriented representation focused on using background knowledge to identify primitive actions and infer subactions and state changes.
- Various constraints establish thematic roles and verb meanings. Once a thematic-role frame is instantiated, it can be used to answer questions about who or what played what role in an action.
- Instantiated primitive-action frames and state-change frames can be used to answer questions about what probably was done or what probably happened next.

## BACKGROUND

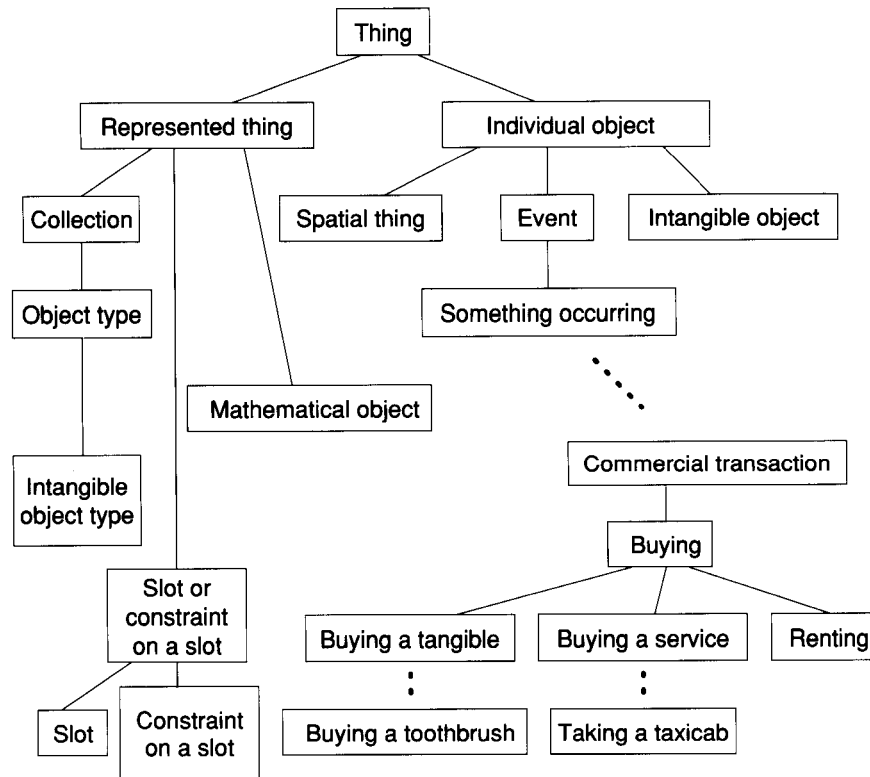
C. J. Fillmore is closely associated with thematic-role grammar, which he called **case grammar** [1968]. Many of the ideas in this chapter were more directly influenced by the late William A. Martin. Most of his work was never published, regrettably.

# APPLICATION

## CYC Captures Commonsense Knowledge

The most ambitious knowledge-representation effort in artificial intelligence is the CYC project, so named because one main goal of the project is to recast much of the knowledge you would find in a desk encyclopedia so as to make that knowledge accessible to reasoning programs.

Believing there is no way to be intelligent without knowing a lot, the developers of CYC have created a vast network of concept-describing frames. A tiny fraction of the frames in that vast network, along with a tiny fraction of the links connecting the frames in that tiny fraction, is shown here:



Various specialized reasoning modules work with many types of links, not just with the inheritance links shown in the illustration. Thus, inheritance is just one of many methods that CYC can use to reach conclusions. At the moment, CYC has more than 4000 link types and dozens of specialized reasoning modules.

Knowledge is entered by **ontological engineers**, who use a sophisticated human-machine interface to increase the speed and reliability of knowledge entering. So far, they have entered more than 5,000 distinct, but richly interconnected frames.

The basic book on Basic English is *Basic English: International Second Language*, by C. K. Ogden [1968]. It is a delightful book, which demonstrates that a small vocabulary can convey a lot of information. The purpose was to promote a subset of English to solve the tower-of-Babel problem.

Yorick A. Wilks contributed importantly to establishing the value of canonical primitives for representing what sentences say on a deeper level [1972]. The work of Roger C. Schank is better known, however, and the discussion of action and state-change frames is based on his work [Schank and Colby 1973].

For arguments against canonical primitives see William A. Woods's classic paper, "What's in a Link" [1975].

The CYC project was conceived, championed, and developed by Douglas B. Lenat. For a comprehensive review, see *Building Large Knowledge-Based Systems* [Lenat and R. V. Guha 1990].