

DEIXIS IN NARRATIVE
A Cognitive Science Perspective

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COMPUTATIONAL REPRESENTATION OF SPACE

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The purpose of this chapter is to provide an analysis of the domain of spatial information and the spatial reference frame problem in the context of understanding natural language narratives, and to present a model for solving the reference frame problem.

In the following sections, we provide the analysis of spatial information and the reference frame problem, describe three strategies and six heuristic rules¹ for resolving reference frame problems, and describe the computational system that demonstrates the model for resolving reference frame problems. We then provide examples of an AI system, called Cassie, processing a short narrative requiring various types of spatial information.

Spatial Information and the Reference Frame Problem

Spatial information may include information about the position, motion, orientation, shape, extent, topology, and so on, of objects or events. If direction of any kind is involved, the meaning of a spatial expression depends on what direction was indicated, the ground relative to which the direction was given, the context in which the direction was mentioned, and so on. As Clifford described (1955), spatial information is essentially relational:

Just as the "George" has only position relative to the other buildings in the town, or the town itself relative to other towns, so a body in space has only position

¹Nine additional rules are proposed in Yuhan (1991).

relative to other bodies in space. To speak of the position of the earth in space is meaningless unless we are thinking at the same time of the Sun or of Jupiter, or of a star—that is, of some one or other of the celestial bodies. (p. 135)

Spatial information about some event or object is given as a relation with respect to some reference, whether that reference is a point, a line, a plane, or anything else, abstract or concrete, explicitly or implicitly expressed. Whereas in linguistic expressions, reference is ordinarily made to some presupposed object, in spatial references about a directional relation, the reference object alone cannot fully clarify the spatial information involved. A grid-like system is needed around the reference object to determine the meaning of directionality. For this reason, understanding of a spatial expression is not complete unless the object serving as the hinge of the reference is properly identified, and the orientation of an imaginary grid-like system serving as the frame of the reference is properly recognized. As Talmy (1978; 1983) noted, the fundamental mechanism of linguistic description of spatial information is the projection of a schema in which a figure object's spatial situation is depicted against a ground object within a stationary reference frame. Henceforth, we define the *reference frame* to be an appropriately established orientational system centered at a certain reference origin. This definition is largely consistent with notions of reference frames discussed in the literature. Our definition of spatial reference frame is an attempt to formalize a recognized problem rather than an attempt to identify a new problem.

In ordinary uses, the ground, which functions as the reference point of the spatial information expression, is given explicitly, whereas the reference frame is mostly implicit. But without determination of the correct reference frame, understanding of spatial information is uncertain and incomplete. Clark's example clearly showed this point:

[...] to the girl lying on the beach, one could say, "There is a fly three inches above your knee," and this could be taken to mean either "There is a fly flying three inches vertically from your knee," or "There is a fly on your leg three inches headward from your knee." (Clark, 1973, p. 44)

This ambiguity arises from the fact that the fly scene can be pictured within either of two competing reference frames: one characterized by the up-down direction determined by the gravitation-based geographical reference frame, and another characterized by the up-down direction determined by the human body's canonical posture based on the ground object's intrinsic reference frame.

We adopt Sondheimer's (1976) terminology, reference frame problem, to refer to the problem of establishing the most appropriate reference frame to interpret a given spatial expression. The decision-making involved in resolving the problem goes beyond recognizing the surface form of the expression. Often, the reference frame problem is not completely resolved by the information in, or inferred from

the utterance. Hearers frequently rely on their visual sense to establish an unequivocal reference frame. For instance, in the example of a girl at the beach, the girl may visually check the competing alternatives. Although reference frame problems may be resolved in different ways by different people, we consider only the problems found in narrative texts in which people generally agree on the reference frames.

AN ANALYSIS OF NARRATIVE SPACE

Semantic Structure of Spatial Events

An event can be represented as a proposition that something occurred at a certain time and at a certain place. We refer to the time as the *event time*, the place as the *event place*, and the something that occurred as the *event affair*. The event affair can be represented as a proposition. For example, in Sentence 1:

- (1) In his office yesterday, Jim called Tom.

the event time is "yesterday" (relative to whenever today is understood to be), the event place is Jim's office, and the event affair is the proposition *Jim call Tom*. A *spatial event affair* is an event affair involving a motion or station of any participant. The event affairs expressed by the Sentences 2a and 2b:

- (2) a. Mary stayed in the room.
b. Tom pitched a ball to the catcher.

are spatial because the sentences are about Mary's station in the room and the ball's move to the catcher.

Surface Conflation of Spatial Verbs

A spatial event may consist of two underlying propositional components. One is the proposition representing the move or station of the figure object, and the other is the one representing the activity (initiated by the agent) that causes, accompanies, or contains in it a move of the figure constituent. For instance, Sentence 2b can be analyzed into two separate deep level propositions—one that describes Tom's activity of throwing a ball in the direction aligned to the catcher, and another that describes the ball's move from Tom to the catcher. Thus, the surface expression, *Tom pitched a ball to the catcher* is thought of as a *conflation* at the surface level of the two underlying propositions. For convenience, we call the component that represents the move or station of a figure the *spatial component*, and the component that represents the other activity, the *nonspatial component*. The spatial component is realized as a deep level proposition consisting

of a figure, a deep stative-motional verb (either *BE-LOC* for the figure's station, or *MOVE* for the figure's move), and appropriate spatial case constituents satisfying the stative-motional verb's valence structure. The nonspatial component is realized as a deep level proposition consisting of an agent, a deep verb for the agent's nonspatial activity, and possibly, some other case constituents in the valence structure. Hereafter, we will call this nonspatial activity component associated with the spatial component the *spatially associated activity*, and the act (such as the act of pitching) that constitutes the centroid of the valence structure of the spatially associated activity the *spatially associated act*.

Spatial Deep Cases and Proximity Relations

Spatial relations are usually expressed in English by means of prepositional phrases. At the surface level, a prepositional phrase is begun by a preposition, a compound preposition cluster, or an implicit preposition. Not all spatial prepositions have the same semantic complexity, despite their ostensibly similar syntactic behavior. For example, Sentence 3:

(3) John ran into the room.

can be analyzed as meaning that John was at first at some place outside the room, and John ran to a place *X* where *X* is in the room. This analysis indicates that *into* is a surface composition of *to* and *in*. We view *to* as a predicate that states that an abstract place *X* is the goal of John's move, and *in* as a predicate that states that the abstract place *X* has the particular spatial relation *in* to the room.

Natural language is equipped with a spectrum of spatial relations (such as *in*, *on*, *above*, *under*, *in front of*, etc.) that relate abstract places to reference objects. Because these spatial relations constitute propositions that assert an abstract place as a satellite place within the semantic vicinity of the ground object, we call them *spatial proximity functions*. These are typically expressed by *directional relations* (such as *in front of*, *behind*, *to the left of*), *inclusion relations* (such as *in*, *out of*, *on*, *between*, *beside*), or *distance relations* (such as *near to*, *away from*).

Spatial case relations and various spatial proximity functions are both coded in English by spatial prepositions (as well as by some preposition clusters). Clark (1973) analyzed the propositions *into* and *onto* as compositions of *in* with *to* and *on* with *to*, respectively. Our analysis is an extension of Clark's analysis. English spatial prepositions (and preposition clusters) are a surface amalgamation of a spatial deep case marker with a spatial proximity function. For example, the prepositional phrase, "in the room," in the sentence, *John stayed in the room*, is analyzed as a surface realization of something equivalent to "AT some place *P* where *P* is-IN the room." In other words, this analysis decomposes the surface prepositional phrase *in the room* into a case component containing a deep spatial

case marker AT and an abstract place argument, and a spatial proximity function component that asserts the spatial proximity relation is-IN held by the abstract place to the ground object, *the room*. In Sentences 4a and 4b,

- (4) a. The mouse lives under the tree where Tom found the eagle's nest.
b. The mouse lives under the tree where Tom found many strange rocks.

the places qualified by the two where-clauses are two different places despite their analogous surface syntactic configuration. The analysis that we argue for accounts for this structural ambiguity. That is, Sentence 4a is analyzed as:

- the mouse lives AT a place *X*,
- *X* is under the tree *Y*,
- Tom found the eagle's nest AT *Y*;

and Sentence 4b is analyzed as:

- the mouse lives AT a place *X*,
- *X* is under the tree *Y*,
- Tom found many strange rocks AT *X*.

In these two different analyses, *X* and *Y* are both nominal concepts antecedent to the relative clause in the sentence. Grammar allows the antecedent of the where-clause in both sentences to be either *X* or *Y*, and we adopt whichever interpretation sounds more likely in the real world.

Directional Relations and Their Reference Frames

Object-Inherent Directionality

Some objects (such as *people*, *houses*, and *cars*) are perceived as having inherent directionality, and others (such as *balls* and *rocks*) are not.

Inherent directionalities vary widely from object to object in their dimensionality and saliency. First, the inherent directionality of an object may be *incomplete*—it may not determine directions in all three basic dimensions. For instance, a *tree* has a very strong inherent up/down but no front/back or left/right directionality. Second, the degree of saliency of the inherent directionality can be quite different from one object to another. A *telescope* seems to have an inherent front/back directionality of mild strength compared to a person. We now examine various ways in which objects come to have inherent directionalities, as a result of semantic extension from the ontological foundations of the three basic directionalities.

Inherent Up/Down. Objects have come to have an inherent up/down directionality through semantic irradiation, or faded metaphor.

“Semantic irradiation” (Bréal, 1924) is a process of semantic change or semantic extension by which a certain form, which was initially meaningless, comes to be associated with a certain meaning after the form has been repeatedly used in contexts containing the particular semantic material. The *canonical posture* of an object is the normal, usual, and default stance of the object. Due to this posture’s being cognitively the most typical, statistically the most frequent, and functionally the most natural, the up/down directionality ontologically originating from the earth’s gravity is irradiated into the object giving it an inherent up/down even when not in its canonical posture.

If an expression, originally used metaphorically, becomes widely accepted and becomes an ordinary usage, it is then a *faded metaphor* (Sturtevant, 1917/1961). When the idea of the pressing force of gravity is metaphorically transferred to nongravitational situations such as, “under the thumbtack on the bulletin board,” we have cases in which the up/down directional terms appear to be used with their reference frame shifted from the direction of the gravitational force to the direction of the exertion of the force involved.

Inherent Front/Back. The prototype front/back directionality around the egocentered perceiver is abstracted and extended to other animate (or inanimate) objects, letting them take the role of the perceiver. In this way, the inherent front/back directionality is recognized around other people, other animals, or even inanimate objects that become an extension of the perceiver.

Because mobility is such an important property of animate objects, if an object is designed to move in a particular direction with respect to its body, we attribute to the object an inherent front/back directionality aligned along the path of motion.

The front/back directionalities based on objects’ autonomous cognitive or kinetic properties are *autonomously inherent* to the objects. But there is a directionality derived more passively. When people encounter other people, they typically do so front side to front side in order to keep their communication channel open. Clark (1973) called it *canonical encounter*. People encounter objects such as houses, computer terminals, or desks, that have a preferred side to be accessed. This canonical access gives the accessed object an inherent front/back in the direction of the accessing— along the direction of the canonical encounter. This kind of front/back directionality is assigned to objects through their encounter with sentient beings, and so is *passively inherent* to the objects.

The inherent front/back directionality found in objects’ static canonical position is *canonically inherent* to the objects. However, when an object is in motion along a particular path, there may arise a sense of front/back directionality whose reference frame is aligned with the path regardless of the object’s own orientation or shape. This directionality is based on dynamically understood contingent characteristics of the object and is *contingently inherent* to the object.

Inherent Left/Right. Left/right directionality does not have an ontological base of its own. If an object has both inherent up/down and front/back directionality, then its inherent left/right directionality depends on whether or not it is viewed as three-dimensional. Every three-dimensional object which has an inherent left/right directionality also has both inherent up/down and inherent front/back directionalities.

Perspectively Imposed Directionality

In natural language, we find that the meaning of some directional terms cannot be attributed to any object explicitly cited or presupposed in the context. Here, we examine the notion of the perspective ego as an imaginary human being implicitly understood in narrative contexts, and claim that such senses of directionalities that cannot be attributed to any object’s inherent properties are the ones perspectively imposed by the perspective ego.

The Perspective Ego. Consider Sentences 5a and 5b:

- (5) a. There is a tree *in front of* the house.
b. There is a rock *in front of* the tree.

In (5a), the front/back directionality is part of the house’s inherent properties. However, the front/back directionality explicitly mentioned by the same directional term, “in front of,” in (5b) cannot be regarded as inherent in either of the two objects explicitly mentioned. The front/back directionality referred to in (5b) is understood from the viewpoint of the language users (the speaker and the hearer) who are imagined to be viewing and talking about the depicted scene. In order to account for some uses of directional relations in natural language, we have to introduce an imagined meta-object² from whose point of view the scene is supposed to be viewed, described, and understood. In many studies, the notion of this imaginary entity or something very close to it was captured with a variety of terms, such as *speaker* (Fillmore, 1972), *narrator* (Prince, 1982), *perspective* or *point of view* (Cresswell, 1985; Dijk & Kintsch, 1983; Prince, 1982), *hypothetical observer of the scene* (Cresswell, 1985), the *WHERE* of the deictic center at which the *narrating WHO* is supposed to be located (Rapaport et al., 1989). (For a fuller description of deixis and perspective in narrative, see Galbraith, this volume.)

²This object is a meta-object in that it cannot be regarded as one of the objects the sentence or the discourse is immediately about. Thereby, it is differentiated from ordinary object-level objects such as people, animals, rocks, trees, houses, and so on. For instance, if a subject is asked to count the number of entities referenced in Sentence 5b the answer will be two, to mean the rock and the tree.

This imaginary entity (see also Prince, 1982) clearly has a human nature made abstract. The speaker or writer speaks or writes the narratives, putting himself or herself in the position of this imaginary entity. The hearer or reader listens or reads the narratives, putting himself or herself in the position of this imaginary entity. The reason a text can be understood by readers the way the writer sees it is that they construct and reconstruct the same imaginary entity with the same characteristics at each passage of the text. The entity is perceived as a separate cognitive character with its own identity. We call this imaginary entity the *perspective ego* and will use the term *perspect* to mean the act of the perspective ego's viewing.

Consider Sentence 6:

- (6) One day as the boy was cleaning, hidden from his master's view *behind* a door, he heard the magician say some magic words to a broom. (Lewis & O'Kun, 1982, p. 24)

In this sentence, the door serves as an object that divides the surrounding space into two disjoint subspaces; we cannot tell which direction relative to the door was meant by "behind the door" if it is detached from the context. It is very difficult for us to attribute the front/back directionality of "behind the door" to the inherent front/back of the magician. The magician was not looking at the boy. He was busy performing his magic, changing his posture in various directions. Thus, the most satisfying interpretation of the expression is that the front/back directionality is established by the perspective direction of the perspective ego who is viewing the room from where the magician was working.

Since the perspective ego would not normally be expected to be in any non-canonical stance in order to view the scene, the up/down directionality is not an issue for the perspective ego. (It is aligned with the gravitational up/down.) Left/right is, as we have already seen, dependent on the front/back directionality. Therefore, the question of how the front/back directionality is created is the most important issue for perspectively imposed directionality.

Encountering and Projecting Perspectives. There are two contradicting front/back directionalities imposed by the perspective ego. One is the front/back directionality coming from the perspective ego's own autonomous inherent front/back³ projected into the perceived space; the other is the front/back directionality coming from the passive front/back directionality vested around an encountered object due to its contingent encounter with the perspective ego. This difference is similar to the one we noted between autonomously inherent and passively inherent front/back directionalities of objects. Depending on which front/back directionality prevails, a perspective is said to be either *projecting* or *encountering*. Consider the following two text fragments (7a) and (7b):

³The perspective ego is believed to be a separate cognitive character with its own identity. Thus, it is natural for there to be an autonomously inherent front/back directionality associated with the perspective ego.

- (7) a. You must be properly seated to operate vehicle controls correctly. Sit in a comfortable, erect position squarely *behind* the steering wheel so that your feet can easily operate the floor controls (Canadian Automobile Association, 1977).
b. The convicted will remain *behind* bars for the rest of his life.

The front/back directionality for "behind" in Sentence 7b is, as in Sentence 6, the one perspectively understood from the view point of the perspective ego who stands and encounters the bars and the prisoners from the outside. In this encountering perspective, the front direction is toward the perspective ego from the bars and *the convicted is behind the bars*. The sentences in (7a) were taken from a booklet with instructions addressed to the second person. In this context, the perspective ego views things from the second person's (that is, *your*) viewpoint. The perspective ego is aligned with *you* seated at the driver's seat "in a comfortable, erect position" prepared to drive the car. The inherent front/back of the perspective ego is projected into the space from him or her in this posture in the car. In this projecting perspective, the front direction is toward the steering wheel from the perspective ego and *you are behind the steering wheel*.⁴

Perspective Up/Down. Another kind of perspectively imposed up/down directionality is psychological, without a matching object in the concrete world. In a perspective situation, the location imagined to be occupied by the perspective ego is given a special perceptual property so that it can serve as the viewpoint for the perspective. Hence, we call the point used by the perspective ego in viewing the scene the *perspective viewpoint*.

Generally, the perspective viewpoint is perceived as somewhat elevated over other places so that the perspective ego can maintain a good, natural perspective. The perspective ego perceives a perspectively created imaginary up/down directionality that is real only in his or her psychological space, and the perspective ego feels that he or she is at a higher height than other places in this imagined up/down directionality. If a character approaches nearer the perspective viewpoint, the perspective ego perceives that the character is making an upward move, and vice versa. When the focal character is moving away from the current WHERE-point, the perspective ego perceives that the focal character is making a downward move because of the focal character's movement(s) away from the current perspective viewpoint. For example:

- (8) And I heard my dad stomping *down* the hall. . . . Then I heard the front door open. (Mann, 1973, p. 6)

⁴Rather than understanding it perspectively, one may attempt to account for the behindness used in (7a) by appealing to the car's inherent front/back directionality. The inherent front/back directionality of a car and the front/back directionality projected by the perspective ego sitting inside the car in the prototypical way are not, perhaps, different in their origin.

The text (8) describes the scene from a young boy's perspective in which his father walked out on his family. We know that halls are usually level. Nonetheless, the boy perceived that his father stomped *down* the hall. There is no other way of understanding this up/down reference other than appealing to the perspectively imposed up/down directionality discussed previously.

STRATEGIES FOR RESOLVING THE REFERENCE FRAME PROBLEM

Now, we present a number of strategies, together with some heuristic rules related to those strategies, that help a cognitive agent resolve reference frames following the principles stated in Yuhan (1991). These rules are only heuristic, as they do not guarantee an optimal solution to the reference frame problem. Moreover, some strategies and rules may partially overlap with others in terms of their applicability. Nonetheless, each different strategy has its own merits and justifications. These rules are grouped into three classes: (a) *grammatical rules* are those stated in terms of grammatical factors—the applicability of these rules are tested by examining the expression's grammatical structures, (b) *inferential rules* are those stated as general reasoning rules—the applicability of these rules are tested by invoking inference processes, (c) *default rules* are used when no others lead to a solution.

In this chapter, we present only those rules Cassie currently uses. For a more complete list see Yuhan (1991).

Resort to Overt Messages

The *principle of explicit expression* states that in resolving the reference frame, the cognitive agent first looks for overt messages and clues in the linguistic expression. The strength of such signals can vary widely. Some messages are definite instructions that the cognitive agent is expected to accept unconditionally; others are subtle insinuations merely promoting or demoting one resolution alternative over others. Regardless of its strength, if there is an overt signal that suggests that the reference frame be resolved in a certain way, the processor is obliged to consider it to be most significant. This is encapsulated as:

Strategy 1: Look in the expression for overt linguistic signals that contain a message for reference frame resolution.

This strategy is implemented by the grammatical rules.

Directional Terms of Definite Noun Form. Consider Example 9:⁵

- (9) a. ?Your golf ball is *to the tree's left*.
b. Your golf ball is *to the left of the tree*.

⁵We follow here formal linguists' convention of putting an asterisk or a question mark in front of an unacceptable or an awkward expression.

Our intuition accepts (9b) and rejects, or only reluctantly accepts, (9a). If the ground object does not have an effective inherent left/right directionality, a left/right directional reference using a possessive-phrase construct is inappropriate.

A closer examination of of-phrase and possessive-phrase constructs sheds some light on the basis for this distinction. We seldom say "the eyes of John,"⁶ whereas we easily say "John's eyes." We do not say "the desk's owner" but can say "the owner of the desk." However, we comfortably say either "John's image" or "the image of John," and also either "the desk's top" or "the top of the desk."

The degree of semantic dependency each possessed constituent has with respect to its possessor constituent in the listed expressions is not the same. We can hardly think of John's eyes without thinking of John himself, whereas we normally do not link a person to the desk he or she owns. Legs of a desk are quite tightly associated to the desk, but not as strongly as John's eyes are to John.

Another grammatical distinction is seen in the use of the definite article *the* in English front/back directional references. Consider Sentence 10:

- (10) [When the professor entered the room, he found that his assistant was] *standing in front of the class* [asking some question of a girl] *sitting in the front of the class*. (Hornby, 1974, p. 352)

Hornby remarked that the phrase "sitting in the front of the class" means [being] "in one of the foremost rows facing the teacher" whereas "standing in front of the class" means "facing the pupils" (p. 352). First of all, the syntactic structures of the two phrases (i) *in front of the class* and (ii) *in the front of the class* are equally

<prep> <NP1> of <NP2>

in their lower level analysis. However, depending on whether or not <NP1> is delimited by a definite article, their phrasing is syntactically different. In (i), the cluster of words *in front of* syntactically functions as a preposition phrase and constructs a prepositional phrase (PP) by taking the noun phrase (NP2) as its prepositional object, whereas in (ii), *in* is the preposition that constructs a prepositional phrase (PP) by taking the noun phrase (NP1 of NP2) as its prepositional object. Therefore, (i) makes a front/back directional reference, and (ii) makes a reference of a containment relation in which a reference of a *whole-part* relation is embedded in the ground object constituent. We perceive the girl sitting in the front of the class as a part of the whole-class while perceiving the assistant standing in front of the class as an individual detached from the class in an encounter with it.

⁶Though there is a movie titled *The Eyes of Laura Mars*.

These differences in the two constructs of "in front of" trace back to the difference of the presence or absence of a definite article. The spatial noun *front* is used in (ii) as a definite noun phrase because of the *the* in front of it, whereas it is used in (i) as a nondefinite noun phrase with no determiner. The definiteness property of the phrase "the front" of (ii) indicates that the noun *front* is used *referentially*.⁷ On the other hand, being nondefinite, the noun *front* of (i) is used solely to exhibit its *predicative function* (Lyons, 1977). A referentially used noun presupposes or implies the existence of the referent (Russell, 1905; Strawson, 1950).⁸ The semantics of the expression are hinged on the referent designated by the inherent properties of the noun concept. For this reason, the expression, "in the front of the class," presupposes or implies for the expression's own sake an inherent front of the class to be referenced. On the other hand, a noun used more to function as a predicate than as a referent indicator does not presuppose or imply the existence of the referent. Its use is proper if the noun concept can be interpreted as an intensionally defined relation in the given context. Therefore, the use of the expression, "in front of the class," is proper merely if a location that has the directional relation *front of* with respect to the class can be intensionally understood. The presence of a definite article before a directional term promotes the intrinsic resolution alternative, in which the ground object's inherent is taken as the reference frame (see Yuhan, 1991).

Hence, the grammatical rule in English regarding reference frame resolution:

G-rule 1: Use of a possessive-phrase construct (instead of an of-phrase construct) or a *definite article* (instead of no article) in a directional reference promotes an intrinsic resolution.

Dummy Agents. In discourses or texts of a certain style,⁹ in which the writer/speaker may use an unstressed *we* or *you* to indicate a nonspecific non-focused agent (Longacre, 1983), a dummy agent "you" or "we" may be introduced. In such a case, if the location of the dummy agent is known to the reader/hearer, the dummy agent exhibits a strong tendency of inviting the perspective ego. In Sentence 11:

- (11) With the printer facing you, as shown in Figure 1-3, grasp the left top side of the lid and lift off the entire lid. (Epson, 1982, p. 1-4)

the dummy agent "you" is introduced into the context and its position is determined propositionally by the phrase "With the printer facing you," as well as analogically by the figure. At this point, the perspective ego is invited to the

⁷It is untrue, though, that all uses of definite noun phrases are referential. For details about such notions as *nondefinite* or *referential use*, see Lyons (1977, chap. 7).

⁸We have no intention of reopening the controversy of Russell and Strawson's arguments about whether it is necessarily an implication or only a presupposition.

⁹Longacre (1983) terms discourses of this style, *procedural discourses*.

place where the dummy agent "you" is located, and provides a perspectively imposed directionality that anchors the reference frame of the left/right directional reference in the context. Hence, the grammatical rule:

G-rule 2: A definitely located dummy agent *you* or *we* promotes a perspective resolution in which the perspective viewpoint is *invited* to the place of the dummy agent.

Resort to Discourse Coherence

According to the discourse coherence principle, a cognitive agent expects a newly read expression to have a semantic interpretation relevant to the current discourse context, and therefore tends to look for a reasonable way to have the new information be interconnected to some components in the context. In reference frame resolution, the readers/listeners have a strategy:

Strategy 2: Examine the discourse context for a coherence connection. This strategy is implemented by the inferential rules.

Typical Acts at the Deictic WHERE-Point. Important aspects of a coherent discourse are cohesiveness of the text and the deictic center. The notion of a deictic center in narratives is discussed extensively in other chapters of this volume. Tracking the deictic center in a narrative is not a trivial problem. Nevertheless, when the WHERE-point is identifiable, it tends to play a significant role in resolving the reference frame problem.

One such situation is where an event is placed at a location and the event is one expected at the location as part of a series of events normally developing at that location. In such a case, the inherent properties of the location are more accessible, and resolution-demanding expressions are more likely to cohere to the location. Hence, we have an inferential rule:

I-rule 1: If both the figure and the ground objects are located at a place *L* and the figure's *spatially associated act*¹⁰ is typically expected at *L*, then an inherited resolution is promoted in which *L* serves as the host object.

Consider this situation (12):

- (12) Mary and Tom were in the theater watching a show. Tom was sitting in front of Mary.

In (12), the reader/listener notes that Mary and Tom were in the theater as audience. Because the audience is normally seated in a theater hall while watching

¹⁰The *spatially associated act* denotes the nonspatial act component of a surface conflated spatial verb. A surface conflated spatial verb is an association of a deep spatial verb with a spatially associated act.

a show, *typicality reasoning* on generic concepts of a theater and the audience make the cognitive agent realize that the spatially associated act, *Tom's sitting at a place P*, is one of the typical acts that Tom was expected to do, due to his being in the theater hall. The rule captures that, in a circumstance like this, the directional reference, *the place P is in front of Mary*, is likely to be interpreted with its reference frame anchored in the inherent front/back directionality of the theater hall. The point of this argument is clearer considering a similar situation (13):

- (13) Mary and Tom were in the theater fixing the electric wirings. For a short break, Tom sat in front of Mary, lighting his cigarette.

In (13), too, Mary and Tom were in the theater hall and Tom sat in front of Mary. However, here, *Tom's sitting* is not an event in which Tom was typically expected to be involved as an electrician working in the theater hall. This difference blocks the rule for the inherited resolution from being applied to (13).

Figure Object Attached to the Environment. The reader/listener tends to favor interpretations that have a strong connection to the context. One such situation is when the figure object is *directionally attached* to the environment. Consider Sentence (14):

- (14) Tom was sitting *in front of* Mary.

First of all, let us suppose this sitting event is placed in a hall and that the hall is perceived as an environment of the directional reference. Let us further suppose we know Mary's location in the hall, but not her orientation there. If the reference frame of the directional reference *in front of* is believed to be anchored in the inherent front/back directionality of Mary, we realize that the directional reference in (14) does not yet help us to learn about the directional relation of Tom's location with respect to the hall. On the other hand, if Mary's orientation in the room is known to us or if the reference frame is believed to be anchored in the inherited front/back directionality of the hall, then Tom is directionally attached to the environment.

Whether or not a directional reference causes the figure object to be directionally attached to the environment depends on whether the directionality in which the reference frame is anchored is bound to the environment. That is to say, the orientation of the directionality in question is fixed with respect to the environment.

From this, we claim that a directionality not bound to the environment is less likely to be considered as the anchor of a reference frame when having the figure object attached to the environment is important. Thus, in situations in which environmental interconnection is expected, the amount of attention that an object

receives in terms of serving as the anchor of a reference frame varies, depending on whether or not its inherent directionality is bound to the environment. In general, when a strong contextual interconnection of a directional reference with its surrounding environment is expected, directionalities that are bound to the environment are more likely to be significant in the context. From this, the following rule is derived:

- I-rule 2:* When a contextual connection of the directional reference to the environment is perceived to be important, and the ground object's inherent directionality is bound to the environment, then an intrinsic resolution based on that particular directionality is promoted.

Default Resolutions

When no remarkable clue leading to a particular solution is found, the cognitive agent settles on an interpretation that requires minimal context (the principle of computational economy). This is the strategy:

- Strategy 3:* Rely on default solutions when no particular solution is found enhanced.

The following describes a few rules that define default solutions.

Default Inherited Solution of Up/Down. Because up/down directionalities have their ontological foundation in the terrestrio-gravitational environment where most events of concern to people happen, it is natural that, in the absence of other information, people understand an up/down directional relation in this way.

Hence, we have a default rule:

- D-rule 1:* When the directional reference is in an up/down directionality, if no other alternative is enhanced, then the language user accepts by default an inherited resolution in which the terrestrio-gravitational environment serves as the host object.

Default Intrinsic and Perspective Solutions of Front/Back. Front/back directionalities have their ontological foundation in the way in which a sentient being encounters objects in the environment. This object-centered nature of front/back directionalities leads the language user to prefer an intrinsic resolution in the absence of a reason for something else. However, if the language user does not see an inherent directionality associated with the ground object, an intrinsic resolution is not appropriate. In this case, the language user has to settle on the next simplest resolution. When the ground object cannot be regarded as an encountering sentient being and if there is no conspicuous object to serve as

a host, the next closest alternative to the ontological foundation comes from the language user's regarding the ground object as an encountered object rather than as an encountering one. This is realized as a perspective resolution.

Hence, we have a default rule:

D-rule 2: When the directional reference is in a front/back directionality, if no other alternative is particularly enhanced and if the ground has an inherent directionality, then the language user supports by default an intrinsic resolution.

A COMPUTATIONAL MODEL OF LANGUAGE PROCESSING

Cassie (Cognitive Agent of the SNePS System—an Intelligent Entity) is an AI system built to demonstrate the robustness of our model of natural language narrative understanding. Cassie reads a simple narrative, understands the story, paying particular attention to spatial information, resolves the spatial reference frame problems based on a coherent model of the story kept in her "mind," and maintains and tracks the deictic center. (See Shapiro & Rapaport, this volume, for a general introduction to SNePS/Cassie.¹¹)

Cassie's main component is ENGRAMMAR, a GATN (Shapiro, 1982) grammar that determines all aspects of Cassie's sentence processing. ENGRAMMAR uses the English morphological analyzer provided with SNePS (Shapiro & the SNePS Implementation Group, 1991) and SNIP, the SNePS Inference Package. ENGRAMMAR's sentence processing is divided into four phases:

1. In the *Initial Interpretation* phase, Cassie recognizes the surface form of the sentence, identifies previously known entities referred to by definite descriptions and pronouns, resolves the spatial reference frame, and constructs a SNePS network for the direct interpretation of the sentence. Spatial information is handled by a special spatial module, called in two kinds of situations: to analyze the spatial case of a verb of location or of motion, or to analyze the spatial expression describing the location of an event. In either case, the spatial module separately identifies any given quantity of distance, the spatial localization function, and the ground object against which the localization function localizes the figure object. If the localization function is a directional relation, spatial processing of this information will conclude at the end of the sentence when the spatial reference frame is resolved. Otherwise, the spatial module builds a SNePS representation of the spatial information before returning to the main sentence processor.

¹¹Although this version of Cassie was implemented separately from the other versions of Cassie described in this book, the same design principles were used. In this chapter, we refer to this version of Cassie as simply "Cassie."

2. The *Extended Interpretation* phase is, in this project, devoted to filling in spatial information from spatially conflated surface verbs, such as *sit, stay, lie, go, run, throw, fly*. The conflated information is unbundled into spatial primitive verbs, such as *BE-LOCated, MOVE, or BE-ORIENTed*. This phase also attempts to determine where the figure and the deictic HERE will be located at the end of the activity.

3. The *Immediate Inference* phase in this project is devoted to tracking any MOVing entities, the deictic center, and the contextual goal.

4. The *Extended Inference* phase is provided for simulation of conscious reflection upon what has just been read, for example, when a person reads a detective novel. This phase is not used in the current project.

The two interpretation phases are driven by the grammar, assisted by inference only for finding previously known entities and for resolving the spatial reference frame. The two inference phases are driven by language-independent domain rules represented in the SNePS network.

EXAMPLES OF THE SYSTEM IN ACTION

To demonstrate Cassie's ability to read a narrative and understand the spatial information in it, we present excerpts from a run¹² in which Cassie read the following story¹³:

- S1: Mary, Tom, and Bob went to a theater together in order to see Bob's uncle's show.
- S2: They walked to the front of the hall.
- S3: Bob sat two rows in front of Mary.
- S4: And, Tom sat just behind her.
- S5: They had a few minutes before the show would start.
- S6: Mary was turned around in her seat talking with Tom.
- S7: Then, she saw a person who looked like Bob walking down the aisle toward her with a tall girl on his left.
- S8: Recognizing Mary, he stopped in front of her to say hello.
- S9: Mary glanced back and saw that Bob was still there in his seat.
- S10: The person standing in front of Mary was Jim who was Bob's twin brother.
- S11: She had met him once before.

¹²The version of SNePS/Cassie used for the work reported here was implemented in Franz Lisp and ran on a VAX 780 machine using the UNIX operating system.

¹³This narrative was written by a graduate student who was a native speaker of English. The story was first explained verbally to the writer with an aid of a diagram of the situation. Then, the writer was asked to write a short paragraph to describe the situation. The writer was not aware of the theoretical claims to be made by this research, although he was told that the text would be used for a study of spatial references. The code number assigned to each sentence is only to refer to it in this book.

- S12: Jim and the tall girl found seats a little distance away to Mary's left.
 S13: Then the lights in the hall dimmed.
 S14: They saw Bob's uncle standing behind a lectern to the left of a microphone.

In the following excerpts, Cassie's output is in typewriter font. Normally, after each phase of sentence processing, Cassie prints a terse English version of what she has understood, and also displays the SNePS structures she has built. Because of limited space, we will only show the terse English edited only by adjusting the spaces and line arrangements.

S1: Mary, Tom, and Bob went to a theater together in order to see Bob's uncle's show.

Initial Interpretation

=====

#> I understand that
 a group of individuals namely, Bob, Tom and Mary
 went to a theater;
 and I understand also that
 it was in order to enable another affair, which is
 that a group of individuals namely, Bob, Tom and
 Mary might see a show.

The terse English sentence indicates that Cassie understood the sentential relation between Bob, Tom, and Mary's going to a theater and their seeing a show. We notice that Cassie understood their seeing a show merely as a possible event while taking their going to a theater as a solid fact.

Extended Interpretation

=====

#> Particularly, I note that,
 due to m35 the <going> act of a group of individuals
 namely, Bob, Tom and Mary, the Figure Objects, a
 group of individuals b4, b3 and b2
 where b4 is related to an individual b7 in such a
 way that b7 has a kinship relation of being uncle
 to individual b4
 where b7 possesses an individual b8 where b8 is a
 member of class show
 and b7 is a member of class uncle
 and b4 is named Bob
 and b4 has the property of being human
 and b4 has the property of being male
 and b3 has the property of being human
 and b3 has the property of being male
 and b3 is named Tom
 and b2 has the property of being human

and b2 has the property of being female
 and b2 is named Mary
 MOVEed
 to a place b6 where b6 has a Spatial Relation of
 "ideal-point"
 to the Ground Object, individual b5 where b5 is a
 member of class theater,
 and that, PRESUMABLY at the end,
 the Figure Objects became BE-LOCated
 at place b6, the destination of the MOVE.

Here, Cassie extends the interpretation of the motional act m35, the act of "going to a theater," extracting first the figure objects' motion in terms of the deep verb MOVE, and second the result that the figure objects are presumably BE-LOCated at the goal location at the immediately next time interval after the event time of the MOVE act. Cassie understood that these two underlying deep events are very closely sequenced together in time and were both conflated and expressed by one surface phrase. Therefore, in Cassie's cognitive space, these deep level events are understood as happening in some subintervals of the event time of the going-to-a-theater event while the event time of the MOVE is before the event time of the BE-LOCated.

In the interests of space and readability, in future displays of Cassie's terse English, we will replace occurrences of b2 by Mary, b3 by Tom, b4 by Bob, and b5 by the theater, edit out repetitions of the properties of these entities, and, in general, replace low-level descriptions of entities by higher level English descriptions after their first introduction.

Immediate Inference

=====

Going into an INFERENCE.

#> Furthermore, I infer that, PRESUMABLY,
 Bob, Tom and Mary were BE-LOCated at a place in the
 theater;
 In other words,
 the Figure Objects, Bob, Tom and Mary
 were BE-LOCated at a place b10
 where b10 has a Spatial Relation of "in"
 to the Ground Object, the theater
 at a time interval b20
 b20 is after a time interval b1
 where b1, which is the EPISODE starting time,
 is the Event-Time of m35 an asserted event,
 the <going> act of Bob, Tom and Mary
 and b20 is before a time interval b9
 where b9 is the Event-Time of m30 an unasserted
 event,
 the <seeing> act of Bob, Tom and Mary.

In the immediate inference phase, Cassie goes through a series of inferences to try to figure out the locations where the individuals that Cassie has learned have moved will eventually be BE-LOCated. Cassie knows that a theater has a hall and an aisle as its parts, and that, if someone goes to a theater and the purpose of going there is to see a show there, then the person is presumably IN the theater at some time point, that is after the person goes there but before the person sees the show. First Cassie believes that Bob, Tom and Mary are AT the theater, then infers that they are presumably IN the theater shortly thereafter. Without any reason to reject the presumption, Cassie finally thinks that Bob, Tom and Mary are IN the theater at the time b20, that is after the event time b1 of their going to the theater, and before the event time b9 of the conjectured event of their seeing the show.

```
Deictic-NOW is maintained as b20
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal
```

Cassie updates the contextual parameters, including the deictic center, before she reads the next sentence in the story. The deictic-NOW is the time that Bob, Tom and Mary were in the theater. The deictic-HERE is the place in the theater where Bob, Tom and Mary are; the deictic-WHO is the group consisting of Bob, Tom and Mary. Cassie also understands that the conjectured event that Bob, Tom and Mary may see a show in the near future, is the goal of their being at the deictic-HERE, and maintains m30 as the contextual goal event at this point.

S2: They walked to the front of the hall.

The second sentence contains a few interesting problems that have to be addressed. First, Cassie has to resolve the pronoun *they* appropriately. Second, the noun *hall* is introduced in the text with a definite article although it had never been mentioned before.

```
Initial Interpretation
=====
```

```
#> I understand that
    Bob, Tom and Mary
    walked to the front part of the hall part of the
    theater.
```

The terse English report indicates that Cassie has solved the both problems successfully. First, Cassie understands that the pronoun "they" in the input sentence refers to the group of the three people, Bob, Tom and Mary. Second, Cassie succeeds in understanding that the *hall* is related in a whole/part relation to the

theater that was introduced in the previous sentence. When a noun (object) which has not been mentioned before is first introduced with a definite article, Cassie thinks that an expectation of the object's existence should be foreshadowed in the context. To find out the expectation that will account for the *hall*, Cassie initiated a SNePS inference. Due to Cassie's rule that states that *the theater has a hall as a part of its whole*, Cassie knows there must be a hall which is a part of the theater that they went to. Thus, Cassie succeeds in integrating the newly given object *hall* into the running narrative context.

```
Extended Interpretation
=====
```

```
#> Particularly, I note that,
    due to m106 the <walking> act of Bob, Tom and Mary,
    the Figure Objects, Bob, Tom and Mary
    MOVEed
    to a place b24 where b24 has a Spatial Relation of
    "ideal-point"
    to the Ground Object, individual b23
    where b23 is a part of an individual b22
    where b22 is a part of the theater
    and b22 is a member of class hall
    and b23 is a member of class front,
    and that, PRESUMABLY at the end,
    the Figure Objects became BE-LOCated
    at place b24, the destination of the MOVE.
```

In the extended interpretation phase, Cassie again extracts a MOVE and a resulting BE-LOCated from a conflated surface verb, in this case, "walked."

Note that Cassie does not take the English expression "the front of the hall" as a directional reference. It rather analyzes the phrase as referring to the front part of the theater hall. Although such part references as this evidently originate from directional references, they have rather specific idiosyncratic meanings.

```
Immediate Inference
=====
```

```
Going into an INFERENCE.
NOTHING reportable deduced through the immediate
inference
```

Cassie finds no particularly interesting inferences through the inference phase.

```
Deictic-NOW is maintained as b21
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal
```

The deictic-NOW point has been updated, whereas the deictic-HERE, deictic-WHO and the goal-event stay the same.

S3: Bob sat two rows in front of Mary.

The expression "two rows in front" is a directional reference that raises a spatial reference frame problem. For the expression to be properly understood, the associated front/back directionality has to be resolved and determined.

Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference

In this particular case, Cassie could not resolve the reference frame problem using grammatical clues alone. So, the system initiated inferences to solve the problem based on the contextual connection. One important tactic is examining whether there is a contextual expectation that may provide a candidate host object for an inherited resolution. Therefore, the system tries to examine in what contextual connection Bob (the figure) is expected to be located at the place b32 at the most updated time b31. I-Rule 1 is invoked and resolves the reference frame since Bob and Mary are both in the theater hall and Bob is indeed expected to take a seat in this context.

Initial Interpretation

=====

#> I understand that

Bob sat at a place in-front-of Mary.

Extended Interpretation

=====

#> Particularly, I note that,

due to m123 the <sitting> act of Bob,
the Figure Object, Bob
was BE-LOCated

at a place b32

where b32 has a Spatial Relation of "in-front-of"

to the Ground Object, Mary

with the inheritedly resolved reference frame of SR
anchored to the canonical front/back directionality
of the Host Object, the theater hall.

The detailed English report made during the extended interpretation indicates that the spatial reference frame problem has been resolved by inheriting the canonical front/back directionality of the theater hall.

Immediate Inference

=====

Going into an INFERENCE.

#> Furthermore, I infer that, PRESUMABLY,
Bob was BE-LOCated at a place in a seat;
In other words,
the Figure Object, Bob
was BE-LOCated
at a place b37
where b37 has a Spatial Relation of "in"
to the Ground Object, individual b36
where b36 is a member of class seat
at a time interval b38
b38 is after a time interval b31
where b31 is the Event-Time of m129 an asserted
event,
the <BEing-LOCated> act of Bob
and b31 is the Event-Time of m123 an asserted
event,
the <sitting> act of Bob
and b38 is before a time interval b9
where b9 is the Event-Time of m30 an unasserted
event,
remembered as a contextual goal event,
the <seeing> act of Bob, Tom and Mary.

As indicated in the detailed English report of the immediate inference results, Cassie now understands that Bob is in a seat at the most updated time interval b38, and updates the deictic-NOW to that time interval.

Deictic-NOW is maintained as b38
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal

S4: And, Tom sat just behind her.

The syntactic structure of this sentence is very close to that of the previous one. It contains a pronoun "her" which should be resolved for its actual reference. It also has a directional reference whose spatial reference frame is resolved by I-Rule 1.

Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference
Directional attachment is examined by an inference

Since this sentence shows no special features not previously encountered, in the interest of saving space, we will omit the output of Cassie's interpretations and inferences.

Cassie now understands that Tom is also BE-LOCated in a seat in the theater hall.

Deictic-NOW is maintained as b44
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal

S5: They had a few minutes <before the show would start>.

This sentence has a complex sentential structure, containing an embedded adverbial clause led by an adverbial conjunction.¹⁴

Initial Interpretation

=====
 #> I understand that
 Bob, Tom and Mary
 had an interval.

This sentence conveys no notable spatial information. For our purpose, therefore, there is nothing that requires an extended interpretation or any further inference.

Deictic-NOW is maintained as b45
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal

S6: Mary was turned around in her seat talking with Tom.

The interesting points of this sentence include: the pronoun; the prepositional phrase, "in her seat," that specifies the place of the narrated event; the present participle phrase, "talking with Tom," that describes another action of Mary's that takes place simultaneously with the action expressed by the main clause;¹⁵ the spatial expression, "was turned around," that describes an orientation that is neither a motion nor a location.

¹⁴In fact, this sentence is a good example of a garden-path sentence. The adverbial conjunction "before" can be easily thought of as a preposition. Therefore, Cassie can well be misled at first to think that the sentence is simply *They had a few minutes before the show* until she finds that the sentence does not end at the word "show" but continues with more words, namely, "would start." Furthermore, a prepositional phrase after a noun phrase can be construed as a reduced relative phrase attached to the noun phrase, as in *the soldier with a rifle on his shoulder guarded the gate*, rather than as a detached adverbial phrase, as in *the poacher shot an elephant with an automatic rifle*. A garden path sentence can seriously drain a system's resource if the system takes a wrong path. Depending on which alternative the parsing grammar of Cassie is arranged to pursue first, this input sentence can cause Cassie to go through many expensive backtrackings before it gets to the right analysis of the sentence. In order to save time, we use the angle bracket diacritics to indicate that the utterance delimited by the paired angle bracket is one constituent.

¹⁵Cassie understands this correctly, but this understanding is not reflected in the terse English reports.

Initial Interpretation

=====
 #> I understand that
 at a place in a seat,
 Mary was turned around.

The prepositional phrase "in a seat" was recognized by Cassie as a description of the place of Mary's being turned around.

Immediate Inference

=====
 Going into an INFERENCE.
 Debris of some failed inference are erased¹⁶
 #> Furthermore, I infer that,
 Mary was BE-ORIENTED to the rear part of the
 theater;
 In other words,
 the Figure Object, Mary
 was BE-ORIENTED
 toward a place b69
 where b69 has a Spatial Relation of "ideal-point"
 to the Ground Object, individual b68
 where b68 is a member of class rear
 and b68 is a part of the theater
 at a time interval b51
 where b51 is the Event-Time of m218 an asserted
 event,
 the <being-turned-around> act of Mary.

After the immediate inference, Cassie understands that Mary is oriented toward the rear of the theater.

Deictic-NOW is maintained as b51
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal

¹⁶In the immediate inference phase, Cassie tries to reason out certain expectations that will help her to understand how the story coheres. In the process of the inference, many fragmentary propositions often become asserted even though the inference fails to lead the system to confirm the main issue for which the inference was performed. Although they are truthful pieces of information, we view such fragmentary assertions in the process of inferences as transient assertions existing only on the subconscious level. Therefore, Cassie purges and does not keep such fragmentary pieces of information.

The deictic-NOW is updated to be the time of Mary's turning around. The rest of the Deictic Center and the contextual goal are unchanged.

S7: Then, she saw <a person (who looked like Bob) walking down the aisle toward her with a tall girl (on his left)>.

This sentence starts with a time adverbial word, "then," that signals a special time relative to the deictic-NOW. Because the sentence is syntactically quite complicated, containing three personal pronouns to be resolved, one definite core noun phrase to be fused with the context, one relative clause, one present participle phrase, and a number of prepositional phrases, we used diacritics to facilitate the processing.

Starting the process of the reference frame resolution.
Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference

The two directional references in the input sentence each require a separate reference frame resolution. The order of resolutions depends on the embedding level of the expressions in the recognized sentence structure. Because the expression "on his left" is syntactically more deeply embedded than "down the aisle," it is resolved first. Due to the overt clue indicated by the possessive delimiter for the directional term, it is quickly resolved by relying on grammatical rule G-Rule 1. As the other expression, "down the aisle," is not resolved by any grammatical rules, Cassie tries to resolve it by inference rules. Failing to do so, Cassie finally resolves it inheritedly, using the default resolution rule D-Rule 1.

Initial Interpretation

=====

#> I understand that
Mary saw
a walking act of a person.

The initial interpretation shows that Cassie resolved the pronoun "she" as meaning Mary, and also that Cassie indeed parsed the input sentence suitable to the story context. Essentially, the syntactic structure of the sentence recognized by Cassie is, to describe it informally:

then, Mary saw the event that <a person (who looked like Bob) was walking down the aisle toward Mary herself with a tall girl (who existed on the person's left)>.

Cassie also inferred that the definite noun clause "the aisle," refers to the aisle which is a part of the theater, as the report made after the extended interpretation will show us.

Extended Interpretation

=====

#> Particularly, I note that,
due to m298 the <walking> act of a person,
the Figure Object, individual b76
where b76 is the Ground object of a Spatial
Relation of "left-side"
for location, individual b83
where b83 is the locative of m288 an asserted
event,
the <existing> act of a girl
with the intrinsically resolved reference frame of SR
anchored to the canonical left/right directionality
of the Ground Object itself
and b76 has the property of being human
and b76 has the property of being male
and b76 is the object of m270 an asserted event,
the <looking-like> act of a person
and b76 is a member of class person
MOVEed
via a place b80
where b80 has a Spatial Relation of "downward"
to the Ground Object, individual b70
where b70 is a part of the theater
and b70 is a member of class aisle
with the inheritedly resolved reference frame of SR
anchored to the canonical up/down directionality
of the universal terrestrio-gravitational world
and b80 has a Spatial Relation of "toward"
to the Ground Object, Mary
and that, PRESUMABLY at the end,
the Figure Object became BE-LOCated
at some place b94 on the path;
and also that
due to m288 the <existing> act of a girl,
the Figure Object, individual b81
where b81 has the property of being human
and b81 has the property of being female
and b81 has the property of being m278
and b81 is a member of class girl
was BE-LOCated
at a place b83
where b83 has a Spatial Relation of "left-side"
to the Ground Object, b76
with the intrinsically resolved reference frame of
SR

anchored to the canonical left/right
directionality
of the Ground Object itself.

Cassie extends the initial interpretation of the progressive walking act of the person who looks like Bob into the person's MOVE to a presumed BE-LOCation somewhere on the path.

Immediate Inference

=====

Going into an INFERENCE.
Debris of some failed inference are erased
NOTHING reportable deduced through the immediate
inference

In this experimental system, Cassie deduces no interesting information in the immediate inference even though it would be reasonable to have inferred from the fact that the person b76 was walking down the aisle toward Mary with a tall girl b81 on his left, that the girl also was moving down the aisle toward Mary.

Deictic-NOW is maintained as b75
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal

S8: Recognizing Mary, he stopped in front of her to say
hello.

Syntactically, this sentence consists of three embedded propositional structures. Under the main sentence, it has one presentential present participle adverbial phrase and one postsentential to-infinitive adverbial phrase. It contains two personal pronouns and one directional reference to be resolved.

Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference
Directional attachment is examined by an inference

Here, Cassie tries to resolve the reference frame of the directional reference "in front of her." Cassie finds no grammatical clue for the resolution and tries in vain to resolve it through SNePS inferences by relating it to the context. Eventually, Cassie resolves it relying on the default rule D-Rule 2.

Initial Interpretation

=====

#> I understand that
a person stopped at a place in-front-of Mary;

and I understand also that
it was in order to enable another affair, which is
that
a person might say hello.

Cassie has correctly parsed the main clause and the postsentential to-infinitive adverbial phrase, properly understanding their propositional relations.

Extended Interpretation

=====

#> Particularly, I note that,
due to m329 the <stopping> act of a person,
the Figure Object, individual b76
where b76 is the agent of m336 an asserted event,
the <recognizing> act of a person
and b76 has the property of being male
was BE-LOCated
at a place b98
where b98 has a Spatial Relation of "in-front-of"
to the Ground Object, Mary
with the intrinsically resolved reference frame of SR
anchored to the canonical front/back directionality
of the Ground Object itself.

By extending the interpretation of the surface expression of a person's stopping in front of Mary, Cassie further understands that the person, b76 is BE-LOCated in front of Mary based on the canonical front/back directionality of Mary. Note that Cassie understands this is the same b76 who was walking down the aisle.

Going into the Immediate Inference

=====

Going into an INFERENCE.
Debris of some failed inference are erased
NOTHING reportable deduced through the immediate
inference

Deictic-NOW is maintained as b95
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal

S9: Mary glanced back and saw that Bob was still there
in his seat.

This sentence exhibits a coordination of two clauses conjoined by a coordinative conjunction "and," where the two clauses share a same subject. Cassie can handle certain usages of syntactic constituent coordination. As we saw with the example of "Mary, Tom, and Bob" in the first sentence, Cassie understands

coordination of arbitrarily many core noun phrases that all together constitute a group of individuals. Cassie also understands coordination of clauses either sharing the same subject or having different subjects.

In the input sentence, there is one genuine spatial expression that states that "Bob was still there in his seat." However, we find in the input sentence one interesting kind of expression, "Mary glanced back." This pseudospacial expression borrows spatial EXTENSION notion to visual perception in order to express "glancing" as if the perception of glancing moves from the perceiving agent to the perceived object via the path of sight. The pseudospacial expression in the input sentence exhibits a use of an adverbial particle, "back," borrowed from a spatial preposition; we view the use as a self-grounded directional reference. In a self-grounded directional reference, the figure object itself serves as the ground of the spatial reference. Thus, an expression such as "Mary glanced back" is understood as "Mary glanced back of herself."

Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference
Directional attachment is examined by an inference

Given the self-grounded directional reference, Cassie, finding no obvious grammatical clues, tries—but fails—to resolve the reference frame using inferential rules. Finally, the reference frame is resolved by default rule D-Rule 2.

Initial Interpretation

=====

#> I understand that
Mary saw an existing act of Bob;
and I understand also that
Mary glanced via a place backward from Mary.

Cassie correctly parsed the sentence made of two coordinated clauses sharing one subject, "Mary," and correctly resolved the reference frame of the directional reference by the pseudospacial expression.

Extended Interpretation

=====

#> Particularly, I note that,
due to m368 the <existing> act of Bob,
the Figure Object, Bob
was BE-LOCated
at a place b108
where b108 has a Spatial Relation of "in"
to the Ground Object, individual b107
where b107 is a member of class seat
and b107 is possessed by an individual Bob;
and also that
due to m359 the <glancing> act of Mary,

a pseudo-motion, the perception of
the Figure Object, Mary

EXTENDED

via a place b104

where b104 has a Spatial Relation of "backward"

to the Ground Object, Mary

with the intrinsically resolved reference frame of SR
anchored to the canonical front/back directionality
of the Ground Object itself.

NOTHING reportable deduced through the immediate
inference

Deictic-NOW is maintained as b103

Deictic-HERE is maintained as b10

Deictic-WHO is maintained as m16

m30 is maintained as a contextual goal

S10: The person standing in front of Mary was Jim
who was Bob's twin brother.

There are a number of challenging problems in this particular sentence. It contains one spatial proposition consisting of a front/back directional reference whose reference frame has to be resolved, one reduced relative clause made of a present participle phrase, and one relative clause led by a relative pronoun, "who."

Starting the process of the reference frame resolution.
Contextual expectation is examined by an inference
Directional attachment is examined by an inference

Cassie first tests the contextual expectation in an attempt to resolve the reference frame of the directional reference "in front of Mary" in a duplicated context after erasing the target expectation from the context. The test turns out to be futile. Then, Cassie tests the possibility of directional attachment. Cassie finds that I-Rule 2 is applicable and so does resolve the reference frame.

Initial Interpretation

=====

#> I understand that
a person had the identity status of being Jim.

Cassie's terse report shows how she understood the top level skeleton of the input sentence. Grasping the top level propositional structure of a sentence with a complicated syntactic structure is unlikely without properly parsing the whole sentence correctly.

Extended Interpretation

=====

#> Particularly, I note that,

due to m430 the <standing> act of a person,
 the Figure Object, b76
 was BE-LOCated
 at a place b112
 where b112 is a base equivalent to b98
 and b112 has a Spatial Relation of "in-front-of"
 to the Ground Object, Mary
 with the intrinsically resolved reference frame of
 SR
 anchored to the canonical front/back direction-
 ality
 of the Ground Object itself.

Cassie derived that the person is located at the place where the person is standing. The reference frame of the "in front of" directional reference was intrinsically resolved. Cassie made the correct inference and identified the person standing at location b112, namely, a place in front of Mary, as b76, the person who stopped to say hello at location b98, the place in front of her. Cassie also understood that the two locations b112 and b98 are indeed equivalent.

Immediate Inference

=====
 Going into an INFERENCE.
 Debris of some failed inference are erased
 NOTHING reportable deduced through the immediate
 inference
 Deictic-NOW is maintained as b111
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal
 S11: She had met him once before.

Initial Interpretation

=====
 #> I understand that
 Mary had met a person.
 Deictic-NOW is maintained as b122
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal

This sentence exhibits a perfective aspect and contains two personal pronouns both of which are resolved correctly.

S12: Jim and the tall girl found seats a little
 distance away to Mary's left.

The sentence contains one directional reference whose reference frame has to be resolved, one definite article phrase whose reference should be resolved by SNePS inference, a plural of a countable noun, and a distance specification coupled with a direction.

Starting the process of the reference frame resolution.
 Contextual expectation is examined by an inference
 Contextual expectation is examined by an inference

Attempting to resolve the reference frame of the directional reference "a little distance away to Mary's left" by inference, Cassie performs a few tests to examine the contextual expectations regarding the locative case of the event. The situation appears to warrant the applicability of G-Rule 1 which is activated by the possessive construction used in the directional expression. However, the effect of the rule is weakened because the figures are not close to the ground. When the first test does not work out, Cassie goes into another test in which the focus is on the expectation regarding the event place. This test eventually reveals that I-Rule 1 is applicable to the situation and so resolves the reference frame.

Initial Interpretation

=====
 #> I understand that
 at a place left-away Mary,
 a group of individuals
 namely, a person and Jim
 found some counts of seats.
 Deictic-NOW is maintained as b124
 Deictic-HERE is maintained as b10
 Deictic-WHO is maintained as m16
 m30 is maintained as a contextual goal

After the input sentence is all processed, Cassie updated the deictic-NOW to b124. Information not shown here indicates that this time is somewhere between b122, the last deictic-NOW and b9, the event time of the yet-unrealized goal event.

S13: Then the lights in the hall dimmed.

This sentence contains one definite noun phrase in which another definite noun phrase is embedded. It is not much of a problem for Cassie to recall "the hall" from the story context. However, "the lights" are some individuals which have never explicitly been introduced in the story context. Inference will find *the lights* with the help of a reasoning rule that intuitively states that *for any hall, there exist some lights that are parts of the whole hall.*

Initial Interpretation

=====

#> I understand that
the light part of the hall part of a theater dimmed.

Cassie's terse report after the initial interpretation indicates that Cassie correctly related the light to the context.

Because there are no new or unusual spatial issues involved, we omitted the extended interpretation and immediate inference reports. Only the Deictic-NOW is updated to a new time.

Deictic-NOW is maintained as b126
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal

S14: They saw <Bob's uncle standing behind a lectern
to the left of a microphone>.

This sentence contains a pronoun and a previously mentioned kinship noun phrase that each has to be resolved and two directional references whose reference frames have to be resolved.

Starting the process of the reference frame resolution.
Starting the process of the reference frame resolution.

Both directional references are found within the scope of the dummy agent, "they," that introduces a perspective viewpoint in the input sentence. This sentential structure activates the grammatical rule, G-Rule 2, and resolves the reference frames of both directional references.

Initial Interpretation

=====

#> I understand that
Bob, Tom and Mary
saw
a standing act of an uncle of Bob.

Extended Interpretation

=====

#> Particularly, I note that,
due to m515 the <standing> act of an uncle of Bob,
the Figure Object, Bob's uncle
was BE-LOCated
at a place b135
where

b135 has a Spatial Relation of "left-away"
to the Ground Object, individual b136
where b136 is a member of class microphone
with the perspectively resolved reference frame
of SR
anchored to the encounter left/right direction-
ality
of the Perspective Ego
invited to the inviting object Bob, Tom and Mary
and
b135 has a Spatial Relation of "behind"
to the Ground Object, individual b134
where b134 is a member of class lectern
with the perspectively resolved reference frame
of SR
anchored to the encounter front/back direction-
ality
of the Perspective Ego
invited to the inviting object Bob, Tom and Mary
Deictic-NOW is maintained as b133
Deictic-HERE is maintained as b10
Deictic-WHO is maintained as m16
m30 is maintained as a contextual goal

The terse report shows that the pronoun "They" was resolved as referring to the group Bob, Tom, and Mary. The expression "Bob's uncle" was also understood as referring to the same Bob's uncle that Cassie first read about at the beginning of the story.

The extended interpretation report indicates that the reference frames of the directional references "behind a lectern" and "to the left of a microphone," were both perspectively resolved by a perspective ego invited to the group Bob, Tom and Mary who are viewing the scene.

SUMMARY

We sketched an analysis of spatial information in narratives. We pointed out that understanding directional information requires having a reference frame, and we discussed the reference frame problem—the problem of deciding what the reference frame is for any given description of directional information. We presented six heuristic rules for solving the reference frame problem, and showed the output of a computer program that reads narratives containing directional information, uses the heuristic rules to resolve the reference frame problems, and demonstrates a fair amount of understanding of the narrative text.