Situation Theory and Situation Semantics

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Introduction

Situation semantics is a mathematically based theory of natural language semantics introduced by the mathematician Jon Barwise in 1980, and developed jointly by Barwise and the philosopher John Perry (and subsequently several others) throughout the 1980s. The first major treatment of the new theory was presented in Barwise and Perry's joint book *Situations and Attitudes* [4].

Initially, situation semantics was conceived as essentially synthetic, with a mathematical ontology built up on set theory. Soon after the appearance of [4], however, the authors changed their approach and decided to handle the topic in an analytic fashion, abstracting a mathematical ontology from analyses of natural language use. Situation theory is the name they gave to the underlying mathematics that arose in that manner. From the mid 1980s onward, therefore, situation semantics was an analysis of semantic issues of natural language based on situation theory.

Much of the initial development work in situation semantics was carried out at the Center for the Study of Language and Information (CSLI), an interdisciplinary research center established at Stanford University through a $23 million gift to Stanford from the System Development Foundation (a spin-off from RAND Corporation).

As originally conceived, situation semantics is an information-based theory, that seeks to understand linguistic utterances in tems of the information conveyed. (Although work carried out by Devlin and Rosenberg [9] in the 1990s showed that situation theory could also be used to analyze language use from an action perspective.) Barwise and Perry began with the assumption that people use language in limited parts of the world to talk about (i.e., exchange information about) other limited parts of the world. Call those limited parts of the world *situations*.

In their 1980 paper *The Situation Underground* [3], the first published work on situation semantics, Barwise and Perry wrote of situations:

"The world consists not just of objects, or of objects, properties and

relations, but of objects having properties and standing in relations to one another. And there are parts of the world, clearly recognized (although not precisely individuated) in common sense and human language. These parts of the world are called situations. Events and episodes are situations in time, scenes are visually perceived situations, changes are sequences of situations, and facts are situations enriched (or polluted) by language.

The appearance of the word "parts" in the above quotation is significant. Situations are *parts* of the world and the information an agent has about a given situation at any moment will be just a *part* of all the information that is theoretically available. The emphasis on partiality contrasts situation semantics from what was regarded by many as its principal competitor as a semantic theory, possible worlds semantics.

It is important to realize that, the use of mathematical concepts notwithstanding, in situation theory and situation semantics, situations are taken to be real, actual parts of the world, and the basic properties and relations the situation semantics deals with are taken to be real uniformities across situations (and not bits of language, ideas, sets of n-tuples, functions, or some other mathematical abstractions).

Situation semantics provides a *relational theory of meaning*. In its simplest form, the meaning of an expression ϕ it taken to be a relation

$$d, c \| \phi \| e$$

between an utterance or discourse situation d, a speaker's connection function c, and a described situation e. These concepts will all be described in due course.

Although described as a "theory," situation theory is more profitably approached as a set of mathematically-based tools to analyze, in particular, the way context facilitates and influences the rise and flow of information. Similarly, situation semantics is best approached as a method for analyzing semantic phenomena. This perspective is reflected in the structure of this article. After providing a brief explanation of the key ideas of situation theory and situation semantics, we present a number of specific topics in situation semantics. It is not intended to be a comprehensive coverage. Rather the goal is to provide some indication of the manner in which the methods of situation semantics may be applied.

Information

Information is always taken to be information *about* some situation, and is assumed to be built up from discrete informational items known as *infons*. Infons

are of the form
$$\langle\!\langle R, a_1, \ldots, a_n, 1 \rangle\!\rangle \quad, \quad \langle\!\langle R, a_1, \ldots, a_n, 0 \rangle\!\rangle$$
where R is an n-place relation and $a_1, \ldots, a_n$ are objects appropriate for R.

Infons are not things that in themselves are true or false. Rather a particular item of information may be true or false about a situation. Given a situation, s, and an infon σ, write
$$s \models \sigma$$
to indicate that the infon σ is made factual by the situation s. The offical terminology is that s *supports* σ. Thus,

$$s \models \langle\!\langle R, a_1, \ldots, a_n, 1 \rangle\!\rangle$$

means that, in the situation s, the objects $a_1, \ldots, a_n$ stand in the relation R, and

$$s \models \langle\!\langle R, a_1, \ldots, a_n, 0 \rangle\!\rangle$$

means that, in the situation s, the objects $a_1, \ldots, a_n$ do not stand in the relation R.

Infons may be combined, recursively, to form *compound infons*. The combinatory operations are conjunction, disjunction, and situation-bounded existential and universal quantification. This is discussed later.

Given a situation s and a compound infon σ,

$$s \models \sigma$$

is defined by recursion in the obvious way. The actuality $s \models \sigma$ is referred to as a *proposition*.

Types

From a formal viewpoint, situation theory is many sorted. The objects (called *uniformities*) in the ontology include the following:

- *individuals*, denoted by $a, b, c, \ldots$

- *relations*, denoted by $P, Q, R, \ldots$

- spatial *locations*, denoted by $l, l', l'', l_0, l_1, l_2, \ldots$

- *temporal locations*, denoted by $t, t', t_0, \ldots$

- *situations*, denoted by $s, s', s'', s_0, \ldots$

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- *types*, denoted by $S, T, U, V, \ldots$

- *parameters*, denoted by $\dot{a}$, $\dot{s}$, $\dot{t}$, $\dot{l}$, etc.

These entities are assumed to be — or to correspond to — aspects of the agent's cognition of the world. That is, the agent has a *scheme of individuation* whereby it carves the world up into manageable pieces. This "carving up" may take the form of cognitive individuation or merely behavioral discrimination.

A particular feature of intelligent behavior is the recognition of types. The agent recognizes (either consciously or through its behavior) various types of object, various types of activity, etc.

The *basic types* of the formal theory are:

- TIM : the type of a temporal location

- LOC : the type of a spatial location

- IND : the type of an individual

- REL^n : the type of an n-place relation

- SIT : the type of a situation

- INF : the type of an infon

- TYP : the type of a type (see later)

- PAR : the type of a *parameter* (see later)

- POL : the type of a polarity (0 and 1)

Given an object, x, and a type, T, we write

$$x : T$$

to indicate that the object x is *of* type T.

Parameters

During the development of situation theory and situation semantics, considerable discussion was devoted to the topic of parameters. The reason for this attention was that, uniquely in the ontology, parameters are not individuated (in any direct sense) by the agent; they are theoretical constructs. They do, however, correspond to, and capture within the theoretical framework, important aspects of the

agent's cognitive behavior. It is the very essence of cognitive activity that the agent tracks various connections. For example, an agent aware of the connection between smoke and fire, who knows that smoke is an indication of fire, needs to be able to connect any specific instance of smoke to a specific instance of fire, one directly linked to the perceived smoke. Within situation semantics, parameters capture such linkages. It is through the mechanism of parameters that the general regularities that govern cognitive activity, reasoning, and information flow become applicable in actual circumstances.

For each basic type T other than PAR, there is an infinite collection $T_1, T_2, T_3, \ldots$ of *basic parameters*, used to denote arbitrary objects of type T.

The parameters T_i are sometimes referred to as T-*parameters*.

Notation: $\dot{l}$, $\dot{t}$, $\dot{a}$, $\dot{s}$, etc. to denote parameters (of type *LOC, TIM, IND, SIT*, etc.).

Parameters are place-holders for specific entities, which the theoretical framework uses to track crucial information links. Anchors for parameters provide a formal mechanism for linking parameters to actual entities. An *anchor* for a set, A, of basic parameters is a function defined on A, which assigns to each parameter T_n in A an object of type T.

If σ is a compound infon and f is an anchor for some of the parameters in σ, $\sigma[f]$ denotes the compound infon that results from replacing each parameter $\dot{a}$ in dom(f) by $f(a)$.

In order to provide a more streamlined treatment of various linguistic and (other) cognitive phenomena, situation theory provides a mechanism for restricting the scope of parameters. *Restricted parameters* are constructed as follows.

Let v be a parameter. A *condition* on v is a finite conjunction of infons. (At least one conjunct should involve v, otherwise the definition is degenerate.)

Given a parameter, v, and a condition, C, on v, define a new parameter, $v \upharpoonright C$, called a *restricted parameter*. $v \upharpoonright C$ denotes an object of the same type as v, that satisfies the requirements imposed by C (*in any situation where this applies*). (If C consists of a single parametric infon σ, we write $v \upharpoonright \sigma$ instead of $v \upharpoonright \{\sigma\}$.)

Let $r = v \upharpoonright C$ be a parameter. Given a situation s, a function f is said to be an *anchor* for r in s if:

1. f is an anchor for v and for every parameter that occurs free in C ;

2. for each infon σ in C: $s \models \sigma[f]$;

3. $f(r) = f(v)$.

Infon logic

Using parameters, the formal definition of the *conjunction* $\sigma \wedge \tau$ of two infons σ, τ is as follows.

For any situation, s,

$$s \models \sigma \wedge \tau \;\; \text{iff} \;\; s \models \sigma \text{ and } s \models \tau.$$

The conjunction is not itself an infon, but a *compound infon.*

The *disjunction* of two infons σ, τ is a compound infon $\sigma \vee \tau$ such that for any situation s,

$$s \models \sigma \vee \tau \;\; \text{iff} \;\; s \models \sigma \;\; \text{or} \;\; s \models \tau \;\; (\text{or both}).$$

The above definitions are in fact clauses in a recursive definition of compound infons.

If σ is an infon (or compound infon) that involves the parameter $\dot{x}$ and u is some set, then

$$(\exists \dot{x} \in u)\sigma$$

is a compound infon.

For any situation, s, that contains (as constituents) all members of u:

$$s \models (\exists \dot{x} \in u)\sigma$$

iff there is an anchor, f, of $\dot{x}$ to an element of u, such that $\;s \models \sigma[f]$.

The anchor, f, here may involve some *resource situation* other than s. f must assign to $\dot{x}$ an appropriate object in some anchoring situation, e, that supports the various infons that figure in the structure of $\dot{x}$.

For example, let σ be the compound infon

$$\langle\!\langle \text{tired}, \dot{c}, t_0, 1 \rangle\!\rangle \wedge \langle\!\langle \text{hungry}, \dot{c}, t_0, 1 \rangle\!\rangle$$

where $\dot{c}$ is a parameter for a cat.

Let s be a room situation at time t_0 and u the set of individuals in s. Then:

$$s \models (\exists \dot{c} \in u)\sigma$$

iff there is an anchor, f, of $\dot{c}$ to some fixed object, c, in u (c necessarily a cat) such that $\;s \models \sigma[f]$, i.e., such that

$$s \models \langle\!\langle \text{tired}, c, t_0, 1 \rangle\!\rangle \wedge \langle\!\langle \text{hungry}, c, t_0, 1 \rangle\!\rangle$$

That is to say, $s \models (\exists \dot{c} \in u)\sigma$ iff there is a cat, c, in u that at time t_0 is tired and hungry in s.

The existence of the anchor, f, entails the existence of an associated *anchoring* (or *resource*) *situation*, e, such that (in particular)

$$e \models \langle\!\langle \text{cat}, c, 1 \rangle\!\rangle$$

In particular, c is a constituent of e.

Note that the object c has to be in the (room) situation, s, at time t_0 in order for the proposition

$$s \models \langle\!\langle \text{tired}, c, t_0, 1 \rangle\!\rangle \wedge \langle\!\langle \text{hungry}, c, t_0, 1 \rangle\!\rangle$$

to obtain.

If σ is an infon (or compound infon) that involves the parameter $\dot{x}$, and if u is some set, then

$$(\forall \dot{x} \in u)\sigma$$

is a compound infon.

For any situation, s, that contains (as constituents) all members of u:

$$s \models (\forall \dot{x} \in u)\sigma$$

iff, for all anchors, f, of $\dot{x}$ to an element of u, $s \models \sigma[f]$.

In the cases both of existential and universal quantification, the bounding set u may consist of all the objects of a certain kind that are in the situation s. Consequently, the definitions do provide a notion of 'unrestricted' quantification, but it is a notion of *situated* quantification.

For an example of situated quantification, when someone truthfully asserts

All citizens have equal rights

they are presumably quantifying over some country such as the United States, not the entire world, for which such a claim is not true.

Type abstraction

Situation theory provides various mechanisms for defining types. The two most basic methods are type-abstraction procedures for the construction of two kinds of types: situation-types and object-types.

Situation-types. Given a *SIT*-parameter, $\dot{s}$, and a compound infon σ, there is a corresponding *situation-type*

$$[\dot{s} \mid \dot{s} \models \sigma],$$

the *type* of situation in which σ obtains.

This process of obtaining a type from a parameter, $\dot{s}$, and a compound infon, σ, is known as *(situation-) type abstraction*. The parameter $\dot{s}$ is called the *abstraction parameter* used in this type abstraction.

For example,

$$[SIT_1 \mid SIT_1 \models \langle\!\langle \text{running}, \dot{p}, LOC_1, TIM_1, 1 \rangle\!\rangle]$$

Object-types. These include the basic types *TIM, LOC, IND, REL^n, SIT, INF, TYP, PAR,* and *POL*, as well as the more fine-grained uniformities described below.

Object-types are determined over some initial situation.

Let s be a given situation. If $\dot{x}$ is a parameter and σ is some compound infon (in general involving $\dot{x}$), then there is a type

$$[\dot{x} \mid s \models \sigma],$$

the *type* of all those objects x to which $\dot{x}$ may be anchored in the situation s, for which the conditions imposed by σ obtain.

This process of obtaining a type $[\dot{x} \mid s \models \sigma]$ from a parameter, $\dot{x}$, a situation, s, and a compound infon, σ, is called *(object-) type abstraction*.

The parameter $\dot{x}$, is known as the *abstraction parameter* used in this type abstraction.

The situation s is known as the *grounding* situation for the type. In many instances, the grounding situation, s, is the world or the environment we live in (generally denoted by w).

For example, the *type* of all people could be denoted by

$$[IND_1 \mid w \models \langle\!\langle \text{person}, IND_1, \dot{l}_w, \dot{t}_{now}, 1 \rangle\!\rangle]$$

Again, if s denotes Jon's environment (over a suitable time span), then

$$[\dot{e} \mid s \models \langle\!\langle \text{sees}, \text{Jon}, \dot{e}, LOC_1, TIM_1, 1 \rangle\!\rangle]$$

denotes the type of all those situations Jon sees (within s).

This is a case of an object-type that is a type of situation.

This example is not the same as a *situation-type*. Situation-types classify situations according to their internal structure, whereas in the type

$$[\dot{e} \mid s \models \ \langle\!\langle \text{sees, Jon}, \dot{e}, LOC_1, TIM_1, 1 \rangle\!\rangle]$$

the situation is typed from the outside.

Constraints

Types and the type abstraction procedures provide a mechanism for capturing the fundamental process whereby a cognitive agent classifies the world. *Constraints* provide the situation theoretic mechanism that captures the way that agents make inferences and act in a rational fashion. Constraints are linkages between situation types. They may be natural laws, conventions, logical (i.e., analytic) rules, linguistic rules, empirical, law-like correspondences, etc.

For example, humans and other agents are familiar with the constraint:

Smoke means fire.

If S is the type of situations where there is smoke present, and S' is the type of situations where there is a fire, then an agent (e.g. a person) can pick up the information that there is a fire by observing that there is smoke (a type S situation) and being aware of, or *attuned to*, the constraint that links the two types of situation.

This constraint is denoted by

$$S \Rightarrow S'$$

(This is read as "*S involves S'.*")

Another example is provided by the constraint

FIRE *means fire.*

This constraint is written
$$S'' \Rightarrow S'$$
It links situations (of type S'') where someone yells the word FIRE to situations (of type S') where there is a fire.

Awareness of the constraint

FIRE *means fire*

involves knowing the meaning of the word FIRE and being familiar with the rules that govern the use of language.

The three types that occur in the above examples may be defined as follows:

$$S \;=\; [\dot{s} \mid \dot{s} \models \;\langle\!\langle \text{smokey}, \dot{t}, 1 \rangle\!\rangle]$$

$$S' \;=\; [\dot{s} \mid \dot{s} \models \;\langle\!\langle \text{firey}, \dot{t}, 1 \rangle\!\rangle]$$

$$S'' \;=\; [\dot{u} \mid \dot{u} \models \;\langle\!\langle \text{speaking}, \dot{a}, \dot{t}, 1 \rangle\!\rangle \wedge \langle\!\langle \text{utters}, \dot{a}, \textit{fire}, \dot{t}, 1 \rangle\!\rangle]$$

Notice that constraints link types, not situations. However, any particular instance where a constraint is utilized to make an inference or to govern/influence behavior will involve specific situations (of the relevant types). Constraints function by capturing various regularities across actual situations.

A constraint

$$C = [S \Rightarrow S']$$

allows an agent to make a logical inference, and hence faciliates information flow, as follows. First the agent must be able to discriminate the two types S and S'. (This use of the word 'discriminate' is not intended to convey more than the most basic of cognitive activities.) Second, the agent must be aware of, or behaviorally attuned to, the constraint. Then, when the agent finds itself in a situation s of type S, it knows that there must be a situation s' of type S'. We may depict this diagrammatically as follows:

$$
\begin{array}{ccc}
S & \overset{C}{\Longrightarrow} & S' \\[4pt]
s : S \uparrow & & \uparrow\, s' : S' \\[4pt]
s & \overset{\exists}{\longrightarrow} & s'
\end{array}
$$

For example, suppose $S \Rightarrow S'$ represents the constraint *smoke means fire*. Agent $\mathcal{A}$ sees a situation s of type S. The constraint then enables $\mathcal{A}$ to conclude correctly that there must in fact be a fire, that is, there must be a situation s' of type S'. (For this example, the constraint $S \Rightarrow S'$ is most likely reflexive, in that the situation s' will be the same as the encountered situation s.)

A particularly important feature of this analysis is that it separates clearly the two very different kinds of entity that are crucial to the creation and transmission of information: one the one hand the abstract types and the constraints that link them, and on the other hand the actual situations in the world that the agent either encounters or whose existence it infers.

It should be noted that the ontology of situation theory has no bottom layer; every individual or situation can be subdivided into constituents, if desired. This

implies that it is possible to represent and analyze a domain at any degree of granularity, to move smoothly up and down the granularity scale during an analysis, and to "zoom" the granularity to investigate specific issues in an analysis, while keeping the remainder of the representation fixed. This feature can play a major role in applications; for example, the analysis of engineer repair reports from a large computer manufacturer, described in [9].

Situation semantics: the basic idea

The object of study in situation semantics is the utterance. In the simplest version, situation semantics analyzes utterances in terms of three situations:

- Utterance situation

- Resource situation

- Focal situation

The utterance situation. This is the context in which the utterance is made and received.

If Melissa says to Naomi

$$A \ man \ is \ at \ the \ door$$

the utterance situation, u, is the immediate context in which Melissa utters these words and Naomi hears them.

The situation u includes both Melissa and Naomi (for the duration of the utterance), and should be sufficiently rich to identify various salient factors about this utterance, such as the door that Melissa is referring to.

This is probably the one in her immediate environment, but not necessarily. For instance, if Melissa utters the sentence *A man is at the door* as part of a larger discourse, the situation u could provide an alternative door.

The connections between the utterance and the various objects referred to, are known as just that: *connections* (or *speaker's connections*).

Thus

$u \models \ \langle\!\langle \text{utters, Melissa}, \Phi, l, t, 1 \rangle\!\rangle \wedge \langle\!\langle \text{refers-to, Melissa}, \textit{the door}, D, l, t, 1 \rangle\!\rangle$

where Φ is the sentence *A man is at the door* and D is a door that is fixed by u.

The speaker's connections link the utterance (as part of u) of the phrase *the door* to the object D.

Resource situations. If Melissa says

The man I saw running yesterday is at the door,

she is making use of a situation that she witnessed the day before, the one in which a certain man was running, in order to identify the man at the door.

There is another situation, r, a situation that occurred the day before the utterance, and which Melissa witnessed, such that

$$u \models \langle\!\langle \text{utters, Melissa, } \Phi, l, t, 1 \rangle\!\rangle \wedge$$
$$\langle\!\langle \text{refers-to, Melissa, } \textit{the man, } M, l, t, 1 \rangle\!\rangle \wedge$$
$$\langle\!\langle \text{refers-to, Melissa, } \textit{the door, } D, l, t, 1 \rangle\!\rangle$$

where Φ is the sentence

The man I saw running yesterday is at the door

and where Melissa is making use of r and the fact that M is the unique man such that (for some appropriate values of l', t')

$$r \models \langle\!\langle \text{runs, } M, l', t', 1 \rangle\!\rangle$$

Resource situations can become available for exploitation in various ways, such as:

1. by being perceived by the speaker;

2. by being the objects of some common knowledge about the world;

3. by being the way the world is;

4. by being built up by previous discourse.

The focal situation. Also known as the *described situation*, the focal situation is that part of the world the utterance is about.

Features of the utterance situation serve to identify the focal situation. For instance, suppose Melissa makes her utterance while peering out of the upstairs window at the house across the street. Then her utterance refers to the situation, s, that she sees, the situation at the house across the street, and we have

$$s \models \langle\!\langle \text{present, } M, l, t, 1 \rangle\!\rangle$$

where l is the location of the door and t is the time of the utterance.

Propositional content

By adopting an ontology that includes items of information (infons), we are able to capture the notion of *the information* encoded by a representation, and can account for the fact that the same information can be encoded by two quite different representations, using quite different representation schemas.

There are then three notions that are often treated as if they were somewhat interchangeable, but which situation theory regards as quite distinct (though related):

- information

- representations

- propositions.

In the case of a linguistic utterance, say Jon's utterance of the assertive sentence

Mary is running

the representation is the utterance itself, which we regard as a situation, call it u.

The *propositional content* of the utterance u is the proposition

$$e \models \sigma$$

where e is the focal situation, σ is the infon $\langle\!\langle \text{runs}, M, t_u, 1 \rangle\!\rangle$, M denotes the individual Mary to whom Jon refers, t_u is the time of the utterance, and e is determined by various features of the utterance.

For example, e could be determined by Jon and the listener being part of some larger situation in which this individual Mary is running, or more generally by means of some other form of previously established context of utterance.

The propositional content is what might normally be referred to as the "information conveyed by the utterance".

Linguistic meaning

As we have seen already, the *meaning* of an assertive sentence, Φ, is a constraint, an abstract link that connects the type of an utterance of Φ with the type of the described situation. More generally, we can describe the meaning of other kinds

of sentence, and of a word or phrase, α, and in these cases too the meaning will be a link between appropriate types.

In the case where a speaker utters the word, phrase, or sentence, α, to a single listener, we shall use u to denote the utterance situation, e the (larger) embedding situation, r any resource situation, and s the described situation. We denote the speaker in u by a_u, and the listener by b_u. The time and location of the utterance are denoted by t_u, l_u, respectively.

$U(\alpha)$ denotes the situation-type of an utterance of α, namely:

$$U(\alpha) = [\dot{u} \mid \dot{u} \models \ll\text{speaking-to}, \dot{a_u}, \dot{b_u}, \dot{l_u}, \dot{t_u}, 1 \gg \wedge$$
$$\ll\text{utters}, \dot{a_u}, \alpha, \dot{l_u}, \dot{t_u}, 1 \gg]$$

Situation semantics distinguishes two different kinds of meaning. The *abstract meaning* supplies the answer to the question "What does this word/phrase/sentence mean (*in general*)?", where the word/phrase/sentence is taken out of any context; the *meaning-in-use* answers the question "What does this word/phrase/sentence mean (*as it is being used in this instance*)?", where the word/phrase/sentence is uttered in a particular context. The meaning-in-use is *induced* by the abstract meaning, with the former a particular instantiation of the latter. In the case of an utterance of a sentence, the meaning-in-use is closely related to the propositional content. The *abstract meaning* is represented as an abstract link between two types; the *meaning-in-use* as a relation between pairs of objects, in general not types.

The abstract meaning of a part of speech, α, will be denoted by $\mathcal{M}(\alpha)$; the meaning-in-use of α will be denoted by $\|\alpha\|$.

In the case of individual words, the meaning-in-use provides a link between the utterance situation and the object (possibly an abstract object, such as a relation) in the world that the word denotes.

It should be born in mind that the brief account that follows provides a fairly crude notion of word meaning. In practice, when a word is uttered as part of a sentence or an extended discourse, the overall context of utterance can contribute features to the meaning of that word (in that context).

The meaning of 'I'

In any utterance, u, 'I' denotes the speaker, a_u, of u. The meaning-in-use, $\|\text{I}\|$, of 'I' is the relation that connects u to a_u for any utterance u. So, for given objects u and a,

$$u\|\text{I}\|a \quad \text{if and only if} \quad u : U(\text{I}) \quad \text{and} \quad a = a_u.$$

Thus the meaning-in-use of the pronoun 'I' is a relation linking situations to individuals.

The abstract meaning of 'I', $\mathcal{M}(\mathrm{I})$, is the link between the situation-type

$$U(\mathrm{I}) = [\dot{u} \mid \dot{u} \models \ll\text{speaking-to}, \dot{a}_u, \dot{b}_u, \dot{l}_u, \dot{t}_u, 1 \gg \wedge$$
$$\ll\text{utters}, \dot{a}_u, \mathrm{I}, \dot{l}_u, \dot{t}_u, 1 \gg]$$

and the object-type

$$E = [\dot{a} \mid \dot{u} \models \ll=, \dot{a}, \dot{a}_u, \dot{l}_u, \dot{t}_u, 1 \gg]$$

Notice that there is exactly one type E such that $U(\mathrm{I})[\mathcal{M}(\mathrm{I})]E$ here.

The abstract link $\mathcal{M}(\mathrm{I})$ induces the relation $\|\mathrm{I}\|$ in the fashion:

$$\|\mathrm{I}\| = \{(u, a) \mid u : U(\mathrm{I}) \;\&\; a : E \text{ where } U(\mathrm{I})[\mathcal{M}(\mathrm{I})]E\}$$

The meaning of 'YOU'

In any utterance situation, 'YOU' denotes the listener. Thus the meaning-in-use of the word 'YOU' is such that

$$u\|\text{YOU}\|b \;\text{ if and only if }\; u : U(\text{YOU}) \;\text{ and }\; b = b_u$$

and the abstract meaning, $\mathcal{M}(\text{YOU})$, is the link between the situation-type

$$U(\text{YOU}) = [\dot{u} \mid \dot{u} \models \ll\text{speaking-to}, \dot{a}_u, \dot{b}_u, \dot{l}_u, \dot{t}_u, 1 \gg \wedge$$
$$\ll\text{utters}, \dot{a}_u, \text{YOU}, \dot{l}_u, \dot{t}_u, 1 \gg]$$

and the object-type

$$E = [\dot{b} \mid \dot{u} \models \ll=, \dot{b}, \dot{b}_u, \dot{l}_u, \dot{t}_u, 1 \gg]$$

The meaning of 'HE', 'SHE', 'IT'

Taking the case 'HE' for definiteness, the significant feature of the pronoun 'HE', when considered out of context, is that it is used to denote a male individual. The appropriate type then to figure in the abstract meaning is the type of any male individual:

$$F = [\dot{b} \mid w \models \ll\text{male}, \dot{b}, 1 \gg]$$

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where $\dot{b}$ is an *IND*-parameter and where w denotes the world.

The abstract meaning, $\mathcal{M}(\text{HE})$, will be the link between the situation-type

$$U(\text{HE}) = [\dot{u} \mid \dot{u} \models \ll\text{speaking-to, } \dot{a_u}, \dot{b_u}, \dot{l_u}, \dot{t_u}, 1 \gg \wedge$$
$$\ll\text{utters, } \dot{a_u}, \text{ HE}, \dot{l_u}, \dot{t_u}, 1 \gg]$$

and the object-type F.

Of course, in this case, the abstract meaning does not really capture the main feature of a pronoun, which is to refer to a particular individual of the appropriate gender. Rather, pronouns really acquire meaning when used in a specific context, and accordingly it is the meaning-in-use that is the more important of the two forms of meaning in this case.

Turning to that meaning-in-use, there are two main ways a pronoun can pick up its referent: either through the speaker or else by having some other noun phrase as an antecedent. Consider, for instance, the sentence:

Jon thought he was wrong.

Uttered one way, 'HE' refers to Jon himself; that is to say, the pronoun picks up its referent *anaphorically* from a previous part of the utterance. Alternatively, the speaker could be using 'HE' *diectically*, to refer to some other person, say Jerry. This referent could be provided by the speaker pointing to Jerry, or could be supplied by some previous utterance as part of a discourse, such as:

Jerry said there was a language of thought. Jon thought he was wrong.

Thus the interpretation of an utterance of the pronoun 'HE' requires the provision of a referent by means of the utterance situation. That is to say, the utterance situation, u, must supply some individual $h = i_u(\text{HE})$ (or $h = i_u(\text{HIM})$) such that for some resource situation, r,

$$r \models \ll\text{male, } h, 1 \gg$$

and then, for any a,

$$u\|\text{HE}\|a \text{ if and only if } u : U(\text{HE}) \text{ and } a = i_u(\text{HE}).$$

Notice that the individual $h = i_u(\text{HE})$ need not be a constituent of the utterance situation. Rather the speaker uses, or relies upon, some resource situation, r, and it is that resource situation, r, that has h as a constituent.

Similarly for the other pronouns, 'SHE', 'IT', etc.

The meaning of proper names

Used correctly, a proper name should designate a particular individual. Since many individuals often share the same name, this means that the context should somehow identify the requisite individual the speaker has in mind. Thus for a proper use of the name 'JAN', the utterance situation, u, should provide an individual $p = i_u(\text{JAN})$ such that for some resource situation, r,

$$r \models \ll \text{named}, p, \text{JAN}, 1 \gg$$

and then, for any a,

$$u \| \text{JAN} \| a \ \text{ if and only if } \ u : U(\text{JAN}) \ \text{ and } \ a = i_u(\text{JAN}).$$

As with the case of third-person pronouns above, there is no requirement that the person Jan be present in the utterance situation. Rather Jan is a constituent of the resource situation, r, which the speaker makes use of when he makes his utterance.

Also as with third-person pronouns, the abstract meaning of a proper name does not really capture what names are about in the way that the meaning-in-use does. For example, $\mathcal{M}(\text{JAN})$ is the link between the situation-type

$$U(\text{JAN}) = [\dot{u} \mid \dot{u} \models \ll \text{speaking-to}, \dot{a}_u, \dot{b}_u, \dot{l}_u, \dot{t}_u, 1 \gg \wedge$$
$$\ll \text{utters}, \dot{a}_u, \text{ JAN}, \dot{l}_u, \dot{t}_u, 1 \gg]$$

and the object-type

$$E = [\dot{b} \mid w \models \ll \text{named}, \dot{b}, \text{JAN}, 1 \gg]$$

To point out one particular manner in which the abstract meaning of proper names is simply at too high a level of abstraction to really capture the way names are used, notice that, if a is an individual of type E, then we shall have

$$w \models \ll \text{named}, a, \text{ JAN}, 1 \gg$$

so for some temporal location t we will have

$$w \models \ll \text{named}, a, \text{ JAN}, t, 1 \gg$$

So all this tells us is that, at *some* time, this individual a is named 'JAN'. But of course, people can and do change their names, whereas correct usage of proper names requires using the name that prevails at the appropriate time. And indeed

this may be reflected in the meaning-in-use. In the present framework this could result from the resource situation having the appropriate temporal duration. But there are other possibilities.

For instance, if the word 'JAN' were uttered as part of a complete sentence, then features of the utterance as a whole could provide an appropriate temporal location t_0 so that in the meaning-in-use of the proper name 'JAN' (on this occasion) we have

$$r \models \ll \text{named}, a, \text{JAN}, t_0, 1 \gg$$

where r is a resource situation.

The meaning of nouns

The abstract meaning of a noun, α, is the link between the type, $U(\alpha)$, of an utterance of α, and the type of the object denoted by α. For example, the abstract meaning of the noun 'APPLE' is the link between the situation-type

$$U(\text{APPLE}) = [\dot{u} \mid \dot{u} \models \ll \text{speaking-to}, \dot{a_u}, \dot{b_u}, \dot{l_u}, \dot{t_u}, 1 \gg \wedge$$
$$\ll \text{utters}, \dot{a_u}, \text{APPLE}, \dot{l_u}, \dot{t_u}, 1 \gg]$$

and the object-type of all apples:

$$[\dot{b} \mid w \models \ll \text{apple}, \dot{b}, 1 \gg]$$

where 'apple' here denotes the property of being an apple.

As for meaning-in-use, this concept applies not so much to nouns as to noun phrases. The normal usage of a noun is as part of a noun phrase, and even on those occasions where a noun is uttered in naked fashion, such as when a small child looks at her plate and says "Apple," this can be regarded, for our purposes, as an abbreviation for the noun phrase 'An apple'.

The meaning of verbs

The meaning-in-use of any verb is the link between the verb and the relation it denotes. For example, the verb 'RUNS' corresponds to the relation, R, of running, and for any utterance situation, u,

$$u \| \text{RUNS} \| R$$

(We deal with the issue of tense presently.)

To be consistent with the development so far, the abstract meaning of a verb, say 'runs', should be taken to be the link between the type of an utterance of the word 'RUNS' and the type of all relations of running. However, in this summary account we do not have parameters for relations and do not form relation-types, hence we cannot accommodate such a notion of abstract meaning of verbs. A more complete development, in which relation-types abstraction was allowed, would be able to handle this issue in the manner suggested.

Speaker's connections

Notice that, in each case so far, the meaning-in-use of a word, α, is a relation, $\|\alpha\|$, that links an utterance situation, u, with a certain object, a, either an individual in the case where α is a pronoun or name, or a relation in the case of a verb. The relation $u\|\alpha\|a$ places a constraint on the utterance situation, u, to supply or contain a suitable object.

Given different utterance situations, the same word can be linked to different objects. Around CSLI at the time situation semantics was being developed, the name 'John' was very much dependent on the utterance situation: did the speaker mean John Perry, John Etchemendy, or John Nerbonne (or even Jon Barwise in the case of a *spoken* utterance)?

The notation used to denote the object that the utterance situation, u, provides to correspond to a word, α, via its meaning, is $c_u(\alpha)$. Thus, in the case of a third-person pronoun or a proper name, c_u is the same as the function i_u introduced a short while ago.

In case an utterance of a word or phrase, α, in an utterance, u, makes use of a resource situation, r, this resource situation is denoted by $c_u^{res}(\alpha)$.

In the case where u is an utterance of a sentence, Φ, there will also be a *described situation*, that part of the world the utterance of Φ is about. Denote this situation by $s_u(\Phi)$.

The term *speaker's connections* refers to any or all of the functions c_u, c_u^{res}, and s_u.

Thus the speaker's connections are the functional links between the words the speaker utters and those parts of, or objects in, the world she uses these words to refer to. They thus provide a mathematical realization of the intentionality of speech, the fact that agents use language to talk *about* the world.

Notice that effective communication requires that, in general, the listener is aware of the identity of the described situation, $s_u(\Phi)$, and the values of the speaker's connection function, c_u, and the onus is on the speaker to ensure that

the listener is so aware. In general there is, however, no need for the listener to know the values of the resource-situation function, c_u^{res}. The role played by resource situations is simply that of a supporting background.

For instance, if, in the course of a conversation, a speaker uses the noun 'APPLE', then there must be some resource situation that supports the fact that the object referred to is indeed an apple, and if challenged the listener might well agree that there will be such a situation, but the identity of that resource situation is not in general important.

Speaker's connections and tensed verbs

Consider the following sentences.

> *Mary is running.*
> *Mary was running.*
> *Mary will run.*

In each case, the meaning of the word 'run' (ignoring the morphological differences between 'run', 'runs', 'running') connects this word to the same relation, R, the relation of running. In using a particular tense of this verb, the speaker is providing a reference to a particular time, the time at which the running takes/took place. Situation semantics accounts for this by means of the speaker's connections function. Thus,

- $c_u(\text{IS}) = t_u$

- $c_u(\text{WAS}) = t$ where $t \prec t_u$

- $c_u(\text{WILL}) = t$ where $t_u \prec t$.

The last two often occur in the context of an existential quantification over t.

The meaning of singular noun phrases

We shall restrict attention to meaning-in-use, and leave it to the reader to supply the more general notion of abstract meaning (the link between the utterance type and an appropriate object-type, that induces the meaning-in-use).

We commence with definite descriptions. For example:

(I) THE MAN IN A BLACK HAT

(II) THE PRESIDENT OF THE UNITED STATES

(III) THE KING OF FRANCE

Each of these can be used to denote, or refer to, a specific individual. Such usage of a definite description is known as the *referential* use, which we consider first.

In each of the above three examples then, if we assume the phrase is used to refer to a particular individual, the question arises: where is that individual, i.e. what situation(s) is the individual a constituent of? Clearly, he need not necessarily be a constituent of the utterance situation, or even the larger, embedding situation. In the case of example (I), an utterance of this phrase could well have the relevant individual present in the embedding situation, but most utterances of (II) will not be made in the presence of the US President. And of course no contemporary situation can include an individual that fits the description in (III), since there is no current King of France.

Rather, in making (referential) use of a definite description

$$\alpha = \text{THE } \pi$$

in the utterance situation, u, the speaker is making use of some resource situation, $r = c_u^{res}(\alpha)$, of which the requisite individual is a constituent.

So the meaning-in-use of α, $\|\alpha\|$, links u to an individual $a = c_u(\alpha)$ such that:

1. $r \models \ll \Pi, a, l_\Pi, t_\Pi, 1 \gg$; and

2. a is the unique individual in r with property (i),

where Π is the property (possibly complex) that corresponds to π, namely the property of *being a π*, and where l_Π and t_Π are the location and time associated with Π if this is location or time dependent.

That is to say, for any given situation u and individual a,

$u\|\text{THE } \pi\|a$ if and only if

$u : U(\text{THE } \pi)$ and a satisfies (i) and (ii), where $r = c_u^{res}(\text{THE } \pi)$.

Thus, in the case of example (I), suppose this sentence is uttered at a party, and it is this party (or maybe some time interval within this event) that we take to be the utterance situation, u. Then the legitimate utterance of this phrase, with reference to the situation u itself as resource situation, will require that there is a man in u wearing a black hat, and moreover there is only one such man.

On the other hand, if we take u to be some conversation that is going on at the party, say a conversation about the rock group playing at the other end of the room, then the phrase (I) may be legitimately uttered provided that precisely one man in the rock group is wearing a black hat, *even though at the party as a whole there may be many men wearing black hats.* This is because the conversation itself determines an appropriate resource situation, namely the situation comprising the rock group.

In either case, the entire party as a resource situation or the rock group as a resource situation, the speaker's connections provide a resource situation, r, in which there is exactly one man wearing a black hat (i.e. possessing the complex property associated with the phrase 'MAN IN A BLACK HAT', that is to say, *being* a man in a black hat), and then the meaning of the definite description (I) links the utterance situation u to this particular individual.

Returning now to example (II), this differs from (I) only in that the resource situation will in general be quite distinct from the utterance situation. In fact, for most (referential) utterances of (II), the 'default' resource situation will be the entire USA over some period of time, a situation that may include the utterance situation or be quite disjoint from it.

Finally, sentence (III) is different from the other two in that there is, currently, no individual in the world that fits this description: there is no King of France. Thus a legitimate referential utterance of this phrase can only be made with reference to a resource situation located in the past, at a time when there was such a person

The meaning-in-use of an indefinite description (used referentially) such as

A BLACK CAT

or

A SMALL TOWN IN GERMANY

is defined in a similar way to that of a definite description, the only difference being that the uniqueness condition (clause (ii) in the above) is not required.

Other singular noun phrases are handled similarly. For instance, when used referentially by an individual KD, a phrase such as

MY DOG

functions very much like a definite description, in that there must be a resource situation, r, in which there is one dog, d, that, at the appropriate time t, belongs to KD, that is to say

$$r \models \ll\text{dog, } d, t, 1 \gg \wedge \ll\text{owns, } KD, d, t, 1 \gg$$

and the meaning of this phrase links the utterance situation with that dog.

Sentence meaning

Consider an *utterance situation*, u, in which a *speaker*, a_u, utters a sentence, Φ, to a single *listener*, b_u, at a time t_u and a location l_u. The situation u may be part of a larger, *discourse situation*, d. (Otherwise we take $d = u$.) The situation d is part of some (possibly larger) *embedding situation*, e, that part of the world of direct relevance to the utterance. During the utterance, the speaker may refer to one of several *resource situations*. The utterance u will determine a *described situation*, $s_u = s_u(\Phi)$.

For definiteness, take the utterance of the single assertive sentence

$$\Phi : \quad \textit{Keith bought a dog.}$$

Factors about the utterance situation, u, should, if this utterence is to succeed in imparting to the listener the information Jan wants to convey, determine a unique individual $k = c_u(\text{KEITH})$ such that for some resource situation $r_k = c_u^{res}(\text{KEITH})$:

(1) $r_k \models \ll\text{person, } k, t_k, 1 \gg \wedge \ll\text{named, } k, \text{KEITH}, t_k, 1 \gg$

(2) k is the only such individual in r_k

where, according to the overall context, either t_k includes t_u or else t_k includes the time t introduced below.

The meaning of the word 'BOUGHT' relates Jan's usage of this word to a relation 'buys', and the usage of the past tense determines that for some time, t, preceding t_u :

(3) $s_u \models \ll\text{buys, } k, p, t, 1 \gg$

where p is as below.

Finally, for the utterance to be true, there must be an individual p and a resource situation $r_p = c_u^{res}(\text{A DOG})$ such that

(4) $r_p \models \ll\text{dog, } p, t, 1 \gg$

(5) $s_u \models \ll\text{buys, } k, p, t, 1 \gg$

Let's examine the various components of this analysis, beginning with the resource situation r_k. In making her utterance the way she does, Jan presumably assumes that the listener has some (possibly quite miminal) information about r_k, in particular the information that there is an individual k' such that:

(6) $r_k \models \ll \text{person}, k', t_k, 1 \gg \wedge \ll \text{named}, k', \text{KEITH}, t_k, 1 \gg$

(7) k' is the only such individual in r_k

It is not necessary that the listener can identify the k' here with the individual, k, Jan is referring to, though Jan might well be assuming the listener has such knowledge.

The *assumption* by Jan of a certain shared knowledge about the resource situation, r_k, is what enables her to use the name 'KEITH' the way she does. Though she herself may well have a very extensive stock of information about r_k, the listener's knowledge could be quite meager. It might only amount to the two items (6) and (7) above. More likely, the listener's knowledge of the rules governing English proper names would allow him to conclude in addition that

(8) $r_k \models \ll \text{male}, k', t_k, 1 \gg$

A fairly cursory knowledge of Jan's family circumstances might also provide the listener with the further information

(9) $r_k \models \ll \text{husband-of}, k', a_u, t_k, 1 \gg$

The listener then, requires only quite minimal knowledge about r_k in order for Jan's usage of the word 'KEITH' to be informational. But notice that Jan too actually needs to draw on very little information about r_k in order to make this utterance.

Though more traditional, AI-oriented approaches to this issue might refer to r_k as a 'Keith-*file*', this would be misleading, in that use of the word 'file' suggests a list of facts about Keith, a list to which the speaker and listener may each add new information, and through which they each search for information. This is not at all what is meant here. Rather, associated to this guy Keith is a certain situation r_k, and as the occasion demands, different people can draw on various items of information about r_k (in terms of our ontology, we might say they can utilize various compound infons, σ, such that $r_k \models \sigma$). The situation r_k remains constant here, a fixed situation, part physical and part abstract, intimately associated with Keith. We could, if we wished, refer to the collection of infons that the speaker and listener each know to be supported by r_k, as the speaker's

'Keith-file' and the listener's 'Keith-file', respectively. In which case *these files* are dynamic entities that change with time. But the *situation* r_k remains fixed.

Turning next to Jan's utterance of the word BOUGHT, in keeping with our overall treatment of relations in this study, assume that both the speaker and the listener associate with this word the same relation, *buys*, a complex, structured object relating a number of arguments.

Now look at Jan's usage of the phrase A DOG. This is likewise linked to a certain situation r_p, a situation associated with the dog Keith bought, a situation that supports, among other things, the fact of that dog being a dog.

Notice that Jan may or may not have any direct knowledge of just *which* dog Keith bought. All we can say as theorists is that there must be such a p and an associated resource situation r_p. The use of the indefinite article leaves aside all questions as to the identity of the dog.

Thus, Jan's utterance refers to a situation in which there are two individuals, k and p. The individual k is referred to directly in the utterance, and facts about the resource situation r_k are required in order for the utterance to convey the information Jan intends of it (assuming the obvious intent, discussed below). The individual p is not referred to in the utterance, nor is the resource situation r_p. There must of course *be* such an individual, and associated with that individual there will *be* a resource situation, r_p. But Jan's utterance does not identify them the way it does the individual k and the situation r_k. This distinction will be highlighted in the following discussion about the informational content of the utterance.

Turning now to that informational content, in the most straightforward case, the item of information that Jan wants to convey by means of her utterance is what is referred to as the *propositional content* of the utterance. This is the proposition

$$s_u \models \exists \dot{p} \exists \dot{t} \ll \text{buys}, k, \dot{p}, \dot{t}, 1 \gg$$

where $\dot{p}$ is a parameter for a dog and $\dot{t}$ is a parameter for a time period prior to t_u, for example $\dot{t} = TIM_{56} \upharpoonright \ll \prec, TIM_{56}, t_u, 1 \gg$.

Notice that this content has as constituents the described situation, s_u, the individual k, and the relation *buys*. The speaker makes explicit reference both to the individual k and the relation *buys*. The described situation, s_u, is not referred to in the utterance. Rather the speaker's connections put s_u into the propositional content. Neither the actual time of the buying nor the actual dog bought get into the propositional content.

Contrast this with an utterance of the sentence

$$\Psi : \textit{Keith bought the dog.}$$

Here the propositional content is

$$s_u \models \exists \dot{t} \ll \text{buys}, k, p, \dot{t}, 1 \gg$$

This time the particular dog, p, gets into the propositional content as an articulated constitutent of the utterance. But where does this individual come from? The utterance of this one sentence alone does not serve to identify p. Rather some previous utterance, or some embedding circumstance, has to pick out the particular dog Jan refers to. Normal language use requires that an utterance of sentence Ψ is indeed either preceded by an utterance that supplies the individual, p, referred to in Ψ by the phrase 'THE DOG', or else the utterance is made in a circumstance where other factors serve to make this identification, such as the utterance being made while the speaker and listener are jointly viewing a scene in which there is exactly one dog.

Notice that the fact that the person, k, referred to in any veridical utterance of Φ, is named 'Keith,' does not contribute directly to the meaning of Φ, nor does the fact that the individual bought, p, is a dog, although these are part of the *meanings* of the two words concerned. Rather these facts are reflected in our framework by virtue of the way parameters operate. Any veridical utterance of Φ is constrained to have the word 'KEITH' refer to a person named 'Keith' and the word 'DOG' refer to a dog.

The propositional content of the utterance of an assertive sentence is our theory's way of getting at the principal item of information that, under normal circumstances, the speaker intends to convey by the utterance. As such it is closely related to the meaning of the sentence, which we turn to next.

The abstract meaning of a sentence is an extrinsic feature of the sentence, independent of any particular context of utterance. For the present example, the *abstract meaning* of the sentence Φ is an abstract link, $\mathcal{M}(\Phi)$, that connects the situation-type

$$\begin{aligned} U = [\dot{u} \mid \dot{u} \models &\ll \text{speaking-to}, \dot{a_u}, \dot{b_u}, \dot{l_u}, \dot{t_u}, 1 \gg \wedge \\ &\ll \text{utters}, \dot{a_u}, \Phi, \dot{l_u}, \dot{t_u}, 1 \gg \wedge \\ &\ll \text{refers-to}, \dot{a_u}, \text{KEITH}, \dot{k}, \dot{l_u}, \dot{t_u}, 1 \gg] \end{aligned}$$

and the situation-type

$$E = [\dot{s} \mid \dot{s} \models \exists \dot{p} \exists \dot{t} \ll \text{buys}, \dot{k}, \dot{p}, \dot{t}, 1 \gg]$$

where $\dot{k}$ is a parameter for a person named 'Keith', $\dot{p}$ is a parameter for a dog, and $\dot{t}$ is a parameter for a time period preceding $\dot{t_u}$, say $\dot{t} = TIM_5 \upharpoonright \ll \prec, TIM_5, \dot{t_u}, 1 \gg$.

The meaning-in-use of Φ, $\|\Phi\|$, should link any particular utterance of Φ with the fact of the world (or relevant part thereof) being the way Φ says it should be.

That is to say it is the relation between situations u and v, induced by $\mathcal{M}(\Phi)$, such that:

$$u\|\Phi\|v \text{ if and only if } [u:U] \text{ \& } [s_u(\Phi) \subseteq v] \text{ \& } [v:E]$$

where $U[\mathcal{M}(\Phi)]E$.

The parametric, compound infon that determines the type E above is known as the *descriptive content* of Φ, denoted by $\mathcal{C}(U)$. That is:

$$\mathcal{C}(U) = \exists\dot{p}\exists\dot{t} \ll \text{buys}, \dot{k}, \dot{p}, \dot{t}, 1 \gg$$

It is denoted by $\mathcal{C}(U)$ rather than $\mathcal{C}(\Phi)$, since the descriptive content is really a function of the type of an utterance of Φ, rather than the sentence Φ. In particular, it is U that provides the link between the word 'KEITH' in Φ and the parameter $\dot{k}$ in $\mathcal{C}(U)$. In practice, however, this distinction is often blurred: $\mathcal{C}(\Phi)$ being understood to mean the descriptive content of Φ *with respect to the type of an utterance of* Φ.

The descriptive content captures the 'information template' that produces the principal item of information conveyed by any veridical utterance of the sentence (that is to say, the information about the described situation that consitutes the propositional content of the utterance) when the various parameters are anchored to the appropriate objects.

Thus the descriptive content provides an intermediate layer between the syntactic unit Φ and the propositional content of an actual utterance of Φ. It allows us to account for Barwise and Perry's *efficiency of language*; in this case the fact that the same sentence Φ can be used over and over again, by different speakers, referring to different Keiths and different dogs, to convey the 'same' item of information each time, namely that the particular Keith referred to bought some dog. The descriptive content is thus a uniformity across all propositional contents of all veridical utterances of Φ.

Notice that the descriptive content transcends the actual syntax of Φ. Rather it gets at something deeper than syntax. For example, translations of Φ into different languages will all have the same descriptive content. The sentence is a string of symbols, constructed in accordance with certain rules; the descriptive content is a parametric, compound infon, a genuine object in our ontology. A veridical utterance of the sentence provides anchors for the various parameters in the descriptive content, and the result is that item of information about the described situation that constitutes the propositional content of the utterance.

In other words, if $\sigma = \mathcal{C}(\Theta)$ is the descriptive content of an assertive sentence Θ, then for any utterance, u, of Θ, if f_u denotes the anchor that u provides for the parameters in σ, then the propositional content of this utterance is

$$s \models \sigma[f_u]$$

where $s = s_u(\Theta)$ (the described situation).

The anchors for the parameters in $\mathcal{C}(\Theta)$ are clearly related to what we have called the speaker's connections for some of the words that go to make up Θ. If α is a word or phrase in Θ and if the speaker's connections link α to the individual $c_u(\alpha)$, and if $\dot{a}$ is the parameter in $\mathcal{C}(\Theta)$ that corresponds to α, then

$$f_u(\dot{a}) = c_u(\alpha)$$

The descriptive content of a sentence is essentially a parametric object. According to the convention adopted in this article that there are no parameters for relations, any descriptive content will involve relations, but by and large all other constituents will be parameters. Exceptions would be where a word or phrase has a fixed meaning, independent of context of utterance, such as 'Earth' or 'Mars' or 'Principia Mathematicae'. (Though it is possible to argue for the context dependency of each of these.)

Further discussion of sentence meaning requires the concept of 'impact' of an utterance, introduced later.

Attributive uses of definite and indefinite descriptions

Hitherto our discussion of both definite and indefinite descriptions has been in terms of what is generally known as the *referential* use, where the description is used to refer to a particular individual — a uniquely specified individual in the case of a definite description, not uniquely identified in the case of an indefinite description. There are, however, other uses of noun phrases.

Starting with definite descriptions, consider the following sentences, all involving one of our original examples of a definite description:

1. *The President of the United States lives in Washington.*

2. *George Bush is the President of the United States.*

3. *George Bush, the President of the United States, lives in Washington.*

Sentence 1 has two quite distinct readings. When the noun phrase is used referentially, to refer to the particular individual who happens to be the President of the United States at the relevant time, the propositional content of the utterance (u) is of the form

$$s_u \models \ll \text{lives-in}, p, c, t_u, 1 \gg$$

where

$$p = c_u(\text{THE PRESIDENT OF THE UNITED STATES})$$

and

$$c = c_u(\text{WASHINGTON}).$$

[In fact c is the city of Washington D.C. (a situation in our ontology) and, if the utterance is made at the time of writing this article, in 2004, p is President George Bush (an individual in our ontology).]

In using the phrase 'THE PRESIDENT OF THE UNITED STATES', the speaker makes use of a resource situation r, possibly the whole of the United States, to identify the particular individual p, that is to say, to determine the value of the function c_u for this particular noun phrase.

The second reading of sentence 1 is the *attributive* reading, where the sentence has a meaning roughly the same as:

> *The President of the United States, whoever it is, always lives in Washington.*

Under this reading, the phrase 'THE PRESIDENT OF THE UNITED STATES' does not refer to a particular individual, but rather to the general property of *being* a President of the United States. Under this reading, an utterance, u, of sentence 1 expresses a constraint, and the propositional content of u is:

$$s_u \models (S \Rightarrow T)$$

where

$$S = [\dot{s} \mid \dot{s} \models \ll\text{US-President}, \dot{p}, \dot{t}, 1 \gg]$$

$$T = [\dot{s} \mid \dot{s} \models \ll\text{lives-in}, \dot{p}, c, \dot{t}, 1 \gg]$$

where s_u, the described situation, is probably the entire United States, and where c is the city of Washington D.C., as before.

Turning now to sentence 2, there is clearly no meaningful reading of this sentence in which the definite description 'THE PRESIDENT OF THE UNITED STATES' is used referentially, since that would just amount to the triviality

> George Bush is George Bush.

Under the attributive reading, the phrase 'THE PRESIDENT OF THE UNITED STATES' determines a predicate, the property of being the President of the United States, and the propositional content of an utterance, u, of sentence 2 is:

$$s_u \models \;\ll\text{US-President}, p, t_u, 1 \gg$$

where $p = c_u(\textsc{George Bush})$ is the individual (President) George Bush.

Finally, sentence 3 provides an example of an *appositive* use of a definite description. Uttering the phrase '\textsc{the President of the United States}' as part of sentence 3 provides additional information about the individual named '\textsc{George Bush}' referred to by the subject of the sentence. Among other things it serves to specify precisely *which* George Bush the speaker has in mind.

The propositional content of an utterance, u, of sentence 3 will be:

$$s_u \models \;\ll\text{lives-in}, p, c, t_u, 1 \gg \wedge \;\ll\text{US-President}, p, t_u, 1 \gg$$

where $p = c_u(\textsc{George Bush})$ is the individual (President) George Bush and $c = c_u(\textsc{Washington})$ is the city of Washington D.C.

Notice that, in the case of the attributive reading of sentence 1, the definite description picks out a *function*, $\mathcal{P}$, the function that associates with each time t the current President of the United States at time t, and the propositional content amounts to the claim that for any time t:

$$s_u \models \;\ll\text{lives-in}, \mathcal{P}(t), c, t, 1 \gg$$

A particularly striking example of such a *functional* use of a definite description arises in connection with the so-called Partee Puzzle. This purports to show that it is not always possible to substitute equals for equals, by considering the pair of sentences:

- *The temperature is ninety.*

- *The temperature is increasing.*

A naive substitution of equals for equals in this pair of sentences produces the absurdity

- *Ninety is increasing.*

Of course, such a substitution is not possible, and the question then is "Why not?"

The answer is that in the first sentence, the definite description '\textsc{the temperature}' is used referentially to refer to the actual temperature at the time of utterance, whereas in the second sentence the same definite description is used functionally to refer to the function that links the time to the temperature at that time.

Broadly similar remarks to all the above can be made about indefinite descriptions. For example, paralleling the three examples of sentences involving definite descriptions, the following exhibit the same overall features:

1. *A Scotsman wears a kilt.*

2. *Angus is a Scotsman.*

3. *Angus, a Scotsman, lives in Oxford.*

Impact

Another feature of sentence utterance considered in situation semantics is the *impact*. Every sentence utterance has an impact, regardless of whether that sentence is assertive or not.

As before, u is an *utterance situation*, in which a *speaker*, a_u, utters a sentence, Φ, to a single *listener*, b_u, at a time t_u and a location l_u. In general, u is part of a larger, *discourse situation*, d. The discourse, d, is part of a (possibly larger) *embedding situation*, e, that part of the world of direct relevance to the discourse. The sentence Φ is not necessarily an assertive sentence.

Denote by t_u^+ some time following the utterance. At the current level of generality, it is not possible to say exactly how much later than t_u this time t_u^+ is, nor what its duration is. It depends very much on context. In the case of a command that should be obeyed immediately, t_u^+ could be an interval immediately following the utterance, the time when the command should be obeyed. In the case of the utterance, u, made as part of an ongoing discourse, d, a common value for t_u^+ will be t_v, where v is the next sentence utterance in the discourse.

The *impact* of u, $\mathcal{I}(u)$, consists of compound infons, σ, built up from basic infons of the form $\ll R, \dots, t, i \gg$, where $t \preceq t_u^+$, such that:

- $e \models \sigma$

- $u \rhd [e \models \sigma]$ (more precisely, $u \rhd \{ \ll \models, e, \sigma, 1 \gg \}$).

Intuitively, the impact of an utterance is the (relevant) change in the embedding situation that the utterance brings about. (The parenthetic use of the word 'relevant' here is to exclude such 'irrelevant' changes as the movement of molecules in the air caused by the utterance, etc.)

For example, in the case where Φ is an assertive sentence, where the speaker (a_u) has the straightforward intention of conveying to the listener (b_u) the information comprising the propositional content, p, of u, and where this intention is fulfilled (i.e. the listener does acquire that information), $\mathcal{I}(u)$ contains the infon

$$\ll\text{has-information}, b_u, p, t_u^+, 1 \gg$$

Notice that the speaker's intention here is in terms of the listener having certain information. We do not refer to the belief or knowledge of the listener. To do so would be quite inappropriate. There are many cases where information is conveyed without the listener, or indeed the speaker, either knowing or believing that information. For example, the speaker or listener might be a computer, which can acquire and dispense vast amounts of information but which neither believes nor knows anything. Or again, one suspects that a great many television newsreaders neither know nor believe all the information they read to camera. Conveying information does not require belief or knowledge of that information, though it does of course require that the speaker *has* that information.

One obvious property of the impact is that it serves to distinguish between certain of Searle's five illocutionary acts.

In the case of a directive, one might imagine that the impact will include the listener's act of compliance or non-compliance to the command.

For example, if Naomi says to Melissa

Close the door

then in the case where Melissa obeys the command, the impact of this utterance, u, could include the infon

$$\ll\text{closes, Melissa, } D, l_D, t_u^+, 1 \gg$$

where $D = c_u(\text{THE DOOR})$, or, if Melissa does not obey the command, it could include the infon

$$\ll\text{closes, Melissa, } D, l_D, t_u^+, 0 \gg$$

However, this is not quite right. For as far as the act of communication is concerned, the utterance of a directive has succeeded if, as a result of the utterance, the listener forms the intention to perform the requisite action. Some other factor(s) might frustrate the fulfillment of this intention, but that is independent of the success or failure of the speech act.

Accordingly, what the impact of Naomi's utterance, u, *will* contain is either the infon

$$\ll\text{of-type}, Melissa, I(D), t_u^+, 1 \gg$$

or the infon

$$\ll \text{of-type}, Melissa, I(D), t_u^+, 0 \gg$$

where $I(D)$ is the object-type of having an intention to close the door D.

Whether the directive is in fact obeyed or not is not reflected in the impact. The impact is concerned exclusively with the effects of the utterance *as a speech act*. But notice that it is the nature of a directive that exactly one of the above two intentional-state infons must be in the impact. There is no 'neutral' position, whereby the impact is void of any infon pertaining to Melissa's intention regarding the closing of the door.

That is to say, one feature of a directive is that if u is an utterance of a command 'Do $\mathcal{K}$' then precisely one of

$$\ll \text{of-type}, b_u, I(\mathcal{K}), t_u^+, 1 \gg$$

or the infon

$$\ll \text{of-type}, b_u, I(\mathcal{K}), t_u^+, 0 \gg$$

is in $\mathcal{I}(u)$, where $I(\mathcal{K})$ is the object-type of having an intention to perform the action $\mathcal{K}$.

For a commisive, the impact will be the formation by the speaker of the intention to perform some future action. Thus if Melissa says to Naomi

I will close the door

then the impact of this utterance, u, will include the infon

$$\ll \text{of-type, Melissa, } I, t_u^+, 1 \gg$$

where I is the object-type of having an intention to close the door.

The impact of a declarator will be that act brought about by the utterance. Thus, if Keith says to Dale:

You are now in charge of the department

then the impact of this utterance, u, includes the infon

$$\ll \text{in-charge-of, Dale, D, } t_u^+, 1 \gg$$

where $D = c_u(\text{THE DEPARTMENT})$.

The above examples illustrate the prominent and characteristic role played by the impact in an utterance of a directive, commisive, or declarator. The impact is not such a prominent feature of the utterance of an assertive or an expressive.

Indeed, at the present level of treatment, the impact does not distinguish between assertives and expressives. Both assertives and expressives are considered purely in terms of the information conveyed, in the sense of propositional content.

But this does not mean that the utterance of assertive or expressive sentences does not have an impact, as the following discussion indicates.

From the point of view of discourse analysis, one important feature of the impact is that it enables us to handle the way that, as a discourse proceeds, referents are supplied for subsequently used pronouns and otherwise ambiguous proper names.

For instance, consider the example mentioned earlier, where a speaker says:

The farmer bought a donkey. He beat it.

The discourse, d, here comprises two sentences. Let u_1 be the utterance of the first sentence, u_2 that of the second. The embedding situation, e, extends the discourse and includes the farmer and a donkey. The utterance u_1 introduces the two objects

$$F = c_{u_1}(\text{THE FARMER}) \quad \text{and} \quad D = c_{u_1}(\text{A DONKEY})$$

into the discourse situation. Then, the utterance u_2 may take

$$c_{u_2}(\text{HE}) = F \quad \text{and} \quad c_{u_2}(\text{IT}) = D$$

In this case, the impact of u_1, $\mathcal{I}(u_1)$, includes the infons

$$\ll\text{salient-in, } F, d, t_{u_1}^+, 1 \gg$$

$$\ll\text{salient-in, } D, d, t_{u_1}^+, 1 \gg$$

In general, if u is an utterance of a word/phrase/sentence, α, such that one or more of $c_u(\alpha), c_u^{res}(\alpha)$, or (in the case where α is a sentence) $s_u(\alpha)$ is defined, then if a is any one of these objects, we have

$$\ll\text{salient-in, } a, d, t_u^+, 1 \gg \in \mathcal{I}(u)$$

which implies that

$$e \models \ll\text{salient-in, } a, d, t_u^+, 1 \gg$$

Moreover:

- if $a = c_u(\alpha)$ is an individual that is referred to by α in u, then

$$\ll\text{refers-to},\, a_u, \alpha, a, t_u, 1 \gg\, \in \mathcal{I}(u)$$

- if $a = c_u(\alpha)$ and $r = c_u^{res}(\alpha)$, then

$$\ll\text{resource-for},\, r, a, t_u, 1 \gg\, \in \mathcal{I}(u)$$

- if α is a sentence and $s = s_u(\alpha)$, then

$$\ll\text{speaking-about},\, a_u, \alpha, s, t_u, 1 \gg\, \in \mathcal{I}(u)$$

The function $\mathcal{I}$ is such that, if u_1 is a subutterance of u_2, then $\mathcal{I}(u_1) \subseteq \mathcal{I}(u_2)$, whenever both these sets are defined.

Consider now the following discourse (set in the late 1980s):

Ed : *Did you see the 49ers game yesterday?*

Jan: *Yes, I think Montana is wonderful.*

Ed : *Yes, his last pass to Rice was amazing.*

Let u_1 be the first utterance, that of Ed, let u_2 be the second, Jan's, and let u_3 be Ed's final utterance. Let t_1, t_2, t_3 be the time intervals corresponding to each of these utterances, respectively, and let Φ_1, Φ_2, Φ_3 be the three sentences uttered.

The impact of u_1 includes the introduction into the discourse situation of the San Fransisco 49ers, SFO, as the resource situation, and

$$G = \text{yesterday's 49ers game}$$

as the described situation, the focus of the ensuing discourse.

Thus, $\mathcal{I}(u_1)$ includes the following infons:

$\ll\text{salient-in},\, \text{SFO},\, d, t_1^+, 1 \gg$
$\ll\text{salient-in},\, G, d, t_1^+, 1 \gg$
$\ll\text{refers-to},\, \text{Ed},\, \text{THE 49ERS GAME},\, G, t_1, 1 \gg$
$\ll\text{resource-for},\, \text{SFO},\, G, t_1, 1 \gg$

where in this case t_1^+ denotes the time interval comprising both t_2 and t_3.

In asking the question he does, Ed is assuming that Jan is familiar with the 49ers, that she has access to the situation SFO. In making the initial 'Yes' response she does, Jan confirms that she does indeed have such access. Otherwise, a more appropriate response would have been "Who?" Likewise, her initial "Yes" shows that she is also familiar with the situation G, since she would otherwise have responded "No."

Now, among the facts that Jan knows about the situation SFO is that the quarterback is named Joe Montana. Thus, in making her response, u_2, Jan can take

$$c_{u_2}(\text{MONTANA}) = M \quad \text{and} \quad c_{u_2}^{res}(\text{MONTANA}) = \text{SFO}$$

where M is the individual Joe Montana.

In turn now, the impact of u_2 includes the introduction of the individual M into the discourse situation. That is to say, $\mathcal{I}(u_2)$ includes the infon

$$\ll\text{salient-in}, M, d, t_2^+, 1 \gg$$

where t_2^+ denotes the time interval t_3.

So, in making the utterance u_3, Ed can take

$$c_{u_3}(\text{HIS}) = M$$

in order to make his comment on the pass made by Montana to wide-receiver Jerry Rice.

In the absence of Ed's first utterance however, Jan's remark could equally well have been about the State of Montana. It was the utterance of u_1, with its impact including the introduction of the situation SFO into the embedding situation, that prevented any such breakdown in communication due to the ambiguity of the word 'Montana'.

Likewise, Ed's knowledge of the situation SFO included the fact that its star wide-receiver is a man, R say, called 'Rice', and thereby allowed him to take

$$c_{u_3}(\text{RICE}) = R$$

The success of u_3 (in terms of the conveyance of information) depends upon Jan, the listener, also knowing that the 49ers have a player called 'Rice'. Otherwise, she might have taken the referent of the word 'rice' to be the white, granular substance found on the supermarket shelves, and not the person R that Ed was

talking about. (Well, this is conceivable — the word is ambiguous.) More likely though, Jan's background knowledge of ball games would have forced her to conclude that Ed's use of the word 'rice' must refer to some person by that name, even if she had never heard of that person before. Situation semantics can handle this possibility as well.)

It would be easy to pursue the above investigation to far greater depths. But the intention here is not to carry out a linguistic analysis, rather to indicate how the formal tools of situation theory, including the impact of an utterance, can be used to perform such an analysis.

Situation semantics and Searle's classification of speech acts

The meaning of an assertive sentence has already been defined and investigated. But what is the meaning of other forms of sentence in the Searle classification, the directives, commisives, declarators, and expressives? The machinery we now have available is not only adequate for dealing with utterances of each of these types, it also provides features that distinguish utterances of one category from those of another.

As before, u is an *utterance situation* in which a *speaker*, a_u, utters a sentence, Φ, to a single *listener*, b_u, at a time t_u and a location l_u.

Let U be the type of an utterance of Φ by a_u to b_u, namely:

$$U = [\dot{u} \mid \dot{u} \models \ll \text{speaking-to, } \dot{a_u}, \dot{b_u}, \dot{l_u}, \dot{t_u}, 1 \gg \wedge$$
$$\ll \text{utters, } \dot{a_u}, \Phi, \dot{l_u}, \dot{t_u}, 1 \gg]$$

Start with the expressives, since from the standpoint of our situation semantics these turn out to be very similar to the assertives.

Suppose that the sentence Φ is an expressive:

$$\text{'I am } \Pi\text{'}$$

where Π is some psychological state, such as sorrow or anger. Let E be the situation-type

$$E = [\dot{s} \mid \dot{s} \models \ll \text{of-type, } \dot{a_u}, B(\Pi), \dot{t_u}, 1 \gg]$$

where $B(\Pi)$ denotes the object-type of being in the state Π.

Then $\mathcal{M}(\Phi)$, the abstract meaning of Φ, is the link between the types U and E.

Turning to the meaning-in-use of Φ, this will be a relation linking utterances of Φ (i.e. situations of type U) to situations extending the described situation that are of type E. So one question to answer is what are the possible described situations? The answer is implicit in the nature of an expressive. In uttering an expressive, the speaker, a_u, describes her own state, so that will be the described situation, $s_u(\Phi)$. Then, given situations u and v we shall have

$u\|\text{I AM } \Pi\|v$ if and only if

$$[u : U] \ \& \ [s_u(\Phi) \subseteq v] \ \& \ [v \models \ll\text{of-type}, a_u, B(\Pi), t_u, 1 \gg]$$

In the three remaining categories of utterance, the directives, commisives, and declarators, the main function is not the conveyance of information, as was the case with the assertives and expressives; rather it is the regulatory effect the utterance has on action, either of the speaker or the listener. For such sentences, the impact of the utterance is the most significant feature, not the propositional content.

Consider first the case where the sentence Φ is a directive:

'Do $\mathcal{K}$.'

Let E be the type

$$E = [\dot{s} \mid \dot{s} \models \ll\text{of-type}, \dot{b}_u, I(\mathcal{K}), \dot{t}_u^+, 1 \gg \wedge$$
$$\ll \rhd, \dot{u}, (\dot{s} \models \ll\text{of-type}, \dot{b}_u, I(\mathcal{K}), \dot{t}_u^+, 1 \gg), 1 \gg]$$

where $I(\mathcal{K})$ is the object-type of having an intention to perform the action $\mathcal{K}$.

Then the abstract meaning of the sentence Φ, $\mathcal{M}(\Phi)$, is defined to be the link between the two types U and E. The intention here is that the meaning of a directive is that link which, for a given utterance of the directive, connects the utterance with its compliance (in the sense of forming the intention to do as instructed). This explains the second component in the definition of the type E, which we have expressed in an abbreviated fashion for clarity. The meaning must reflect the fact that the intention to perform the action $\mathcal{K}$ that figures in Φ has to arise by way of complying with the directive.

The meaning-in-use of Φ, induced by $\mathcal{M}(\Phi)$, is a relation, $\|\Phi\|$, between utterances, u, of Φ and certain situations v that extend the described situation, $s_u(\Phi)$. Now the situation $s_u(\Phi)$ is identified by features of the utterance itself. For assertives it can be any situation whatever. For expressives the described situation is constrained to be the speaker's state. In the case of a directive, the described situation must be the listener's state. Then for any two situations u and v:

$u\|\mathrm{Do}\ \mathcal{K}\|v$ if and only if

$$[u:U]\ \&\ [s_u(\Phi)\subseteq v]\ \&\ [v\models\ll\text{of-type},b_u,I(\mathcal{K}),t_u^+,1\gg\wedge$$
$$\ll\rhd,u,(v\models\ll\text{of-type},b_u,I(\mathcal{K}),t_u^+,1\gg),1\gg]$$

Suppose now that Φ is a commisive:

$$\text{`I will }\mathcal{K}\text{.'}$$

Let E be the type

$$E=[\dot{s}\mid\dot{s}\models\ll\text{of-type},\dot{a}_u,I(\mathcal{K}),\dot{t}_u^+,1\gg]$$

where again $I(\mathcal{K})$ is the object-type of having an intention to perform the action $\mathcal{K}$.

The abstract meaning of Φ is again defined to be the link between the two types U and E.

Turning to $\|\Phi\|$, if we are given a particular utterance, u, of the commisive Φ, the described situation, $s_u(\Phi)$, will be the speaker's state, and the meaning-in-use of Φ relates the situation u to those situations v extending $s_u(\Phi)$ in which the speaker forms the intention to do as promised in Φ:

$u\|\text{I WILL }\mathcal{K}\|v$ if and only if:

$$[u:U]\ \&\ [s_u(\Phi)\subseteq v]\ \&\ [v\models\ll\text{of-type},a_u,I(\mathcal{K}),t_u^+,1\gg]$$

Finally, suppose Φ is a declarator:

$$\text{`I declare }\mathcal{K}\text{.'}$$

Let E be the type

$$E=[\dot{s}\mid\dot{s}\models\ll T(\mathcal{K}),\dot{t}_u^+,1\gg]$$

where $T(\mathcal{K})$ expresses that fact that things are as the utterance of Φ declares them to be. For example, if

$$\mathcal{K}=\text{`You are in charge'}$$

then

$$T(\mathcal{K})=\text{in-charge},b_u$$

Then $\mathcal{M}(\Phi)$ is the link between U and E.

For $\|\Phi\|$, if we are given an utterance u of Φ, then there is no general rule as to what is the described situation, $s_u(\Phi)$. It depends very much on $\mathcal{K}$. In the case of the example just given, $s_u(\Phi)$ will be whatever it is the listener is put in charge of, say, the department. Then, given situations u and v, we have:

$u\|\text{YOU ARE IN CHARGE}\|v$ if and only if

$$[u:U] \ \& \ [s_u(\Phi) \subseteq v] \ \& \ [v \models \ll\text{in-charge}, b_u, t_u^+, 1 \gg]$$

Compositionality

This brief article does not sent out to provide a full-blown account of the way that the meaning of a composite sentence or utterance is built up from the meanings of the various components. Certainly the high degree of context dependency of this process would seem to render as a hopeless dream any kind of development analogous to Tarski's semantics of predicate logic. But the tools described are adequate for an analysis of particular instances of compositionality, so it will be a useful exercise to investigate two of the simplest, and most basic kinds of example: conjunction and disjunction. We restrict attention to meaning-in-use.

Start with conjunction. Let u be an utterance situation, in which a speaker a_u utters a conjunctive sentence $[\Phi \text{ AND } \Psi]$ to a single listener b_u at a time t_u and a location l_u. In general, u is part of a larger, discourse situation d. The discourse d is part of a (possibly larger) embedding situation e, that part of the world of direct relevance to the discourse. Let u_1 be the utterance situation in which the clause Φ is uttered, u_2 that pertaining to Ψ.

Naively, one might expect that, given assertives Φ and Ψ, the meaning-in-use of the sentence $[\Phi \text{ AND } \Psi]$ is given by

$$u\|\Phi \text{ AND } \Psi\|v \text{ if and only if } u_1\|\Phi\|v \text{ and } u_2\|\Psi\|v$$

This is indeed the case, but the superficial resemblance this has to the analogous Tarskian rule obscures some considerable complexity.

Suppose for instance the sentence uttered is:

Sid loves Nancy and she loves him.

Then the above reduction gives

$(*)$ $\quad u\|\text{SID LOVES NANCY AND SHE LOVES HIM}\|v$ if and only if

$$u_1\|\text{SID LOVES NANCY}\|v \text{ and } u_2\|\text{SHE LOVES HIM}\|v$$

The first conjunct here is straightforward enough. The speaker's connections should fix two individuals, $S = c_{u_1}(\textsc{Sid})$ and $N = c_{u_1}(\textsc{Nancy})$, such that (in particular)

$$u_1 \models \ll\text{refers-to}, a_{u_1}, \textsc{Sid}, S, l_{u_1}, t_{u_1}, 1 \gg \wedge$$
$$\ll\text{refers-to}, a_{u_1}, \textsc{Nancy}, N, l_{u_1}, t_{u_1}, 1 \gg$$

and

$$v \models \ll\text{loves}, S, N, t_{u_1}, 1 \gg$$

The second clause involves two pronouns, 'SHE' and 'HIM'. The referents for these pronouns must be supplied by the utterance. The most natural case would be where

$$c_{u_2}(\textsc{she}) = N \quad \text{and} \quad c_{u_2}(\textsc{him}) = S$$

and then part of the requirement on v imposed by $(*)$ is

$$v \models \ll\text{loves}, N, S, t_{u_1}, 1 \gg$$

In this case the impact of the utterance u_1 provides the relevant individuals to act as referents for the pronouns used in u_2. But there are other possibilities. The utterance could pick out other individuals to be referents for these pronouns.

The meaning of disjunctive sentences, $[\Phi \text{ OR } \Psi]$, is similar to conjunctions. Thus:

$$u\|\Phi \text{ OR } \Psi\|v \quad \text{if and only if} \quad u_1\|\Phi\|v \text{ or } u_2\|\Psi\|v$$

Remarks analogous to those made in the case of conjunction apply here as well.

Quantification

One of the most significant uses of parameters in situation theory arises in the semantics of natural language quantification. For example, let Φ be the sentence

Every logician admires Quine.

Let u be an utterance of Φ. The first question I ask is what is the described situation, $e = s_u(\Phi)$? Well, in the absence of any previously established context this will surely be the world, w, or at least some part of the world that pertains to, and in particular includes, all logicians — say the academic world. In any event, the propositional content of the utterance u will be of the form

$$e \models <compound\ infon>$$

The question is, just what compound infon occurs here?

The first approach takes as the propositional content of the utterance, u, the proposition:

$$e \models (\forall \dot{p})\ll\text{admires}, \dot{p}, Q, t, 1 \gg$$

or, more precisely (recall the convention regarding quantification in compound infons):

$$e \models (\forall \dot{p} \in e)\ll\text{admires}, \dot{p}, Q, t, 1 \gg$$

where $\dot{p}$ is a partameter for a logician, Q is the individual W.V.O. Quine, and t is the present time. (Taking t to be the time of utterance, t_u, would be inappropriately restrictive in this connection. The time interval t will include t_u but have considerably longer duration. The utterance makes no specific reference to time, though it is clearly intended to be about 'the present time' or perhaps 'the present epoch'.)

By virtue of the manner in which quantifiers operate on infons, this means that for any anchor f for the parameter $\dot{p}$ to an object p in e, it must be the case that

$$e \models \ll\text{admires}, p, Q, t, 1 \gg$$

In order for f to be an anchor for $\dot{p}$, there must be a resource situation, r, such that:

$$r \models \ll\text{logician}, p, t, 1 \gg$$

But there is no requirement that r should be the same situation as e, or indeed bear any particular relation to e. (Though if e is the world, then r will be a subsituation of e, of course.) Indeed, all that is required is that to each p in e to which $\dot{p}$ can be anchored, there will be *some* such resource situation $r = r_p$ that depends on p.

Consider now the sentences

Φ_1 : *Every player touched the ball.*

Φ_2 : *Every player ate a cookie.*

Let u_1 be an utterance of Φ_1, u_2 an utterance of Φ_2.

Starting with Φ_1, the described situation, $s_{u_1}(\Phi_1)$, will be some ball game, say e, and the propositional content of u_1 will be

$$e \models (\forall \dot{p})(\exists \dot{t}) \ll \text{touch}, \dot{p}, b, \dot{t}, 1 \gg$$

where $\dot{p}$ is a parameter for a player, $b = c_u(\text{THE BALL})$, and $\dot{t}$ is a parameter for a time preceding t_{u_1}. The game situation e will provide the resource situation for all the individuals p to which the parameter $\dot{p}$ can be anchored. That is to say, for any anchor f of $\dot{p}$ to an individual p in e, it will be the case that for some time t within the time-span of e:

- $e \models \ll \text{player-in}, p, e, t, 1 \gg$

- $e \models \ll \text{touch}, p, b, t, 1 \gg$

The resource situation for the fact that t precedes t_{u_1} is, as always, the world:

$$w \models \ll \prec, t, t_{u_1}, 1 \gg$$

since this is the nature of the basic type $\prec$.

Turning now to the second sentence, Φ_2, assuming the players eat the cookies during the game, the described situation, $s_{u_2}(\Phi_2)$, will be the game e, as before, and the propositional content of u_2 will be

$$e \models (\forall \dot{p})(\exists \dot{c})(\exists \dot{t}) \ll \text{eats}, \dot{p}, \dot{c}, \dot{t}, 1 \gg$$

where $\dot{p}$ is a parameter for a person and $\dot{t}$ is a parameter for a time preceding t_{u_2}, much as before, and where $\dot{c}$ is a parameter for a cookie. (The reading of Φ_2 whereby every player eats the *same* cookie is too implausible to consider; rather, assume that to each player there corresponds a cookie which that player, and only that player, eats.)

Clearly, there is no reason to suppose the game situation e supports the facticity of any particular individual being a cookie. Nor is it necessarily the case that every cookie eaten by some player is of the same variety, with its cookieness being supported by one and the same resource situation. Rather, for each individual p in e to which $\dot{p}$ may be anchored and each corresponding time t to which $\dot{t}$ is anchored, and for which, therefore

$$e \models \ll \text{player-in}, p, e, t, 1 \gg$$

there will be an individual c and a resource situation r_c, such that

$$r_c \models \ll \text{cookie}, c, t, 1 \gg$$

Given the assumption that the players eat the cookies during the game e, then the cookie c will be a constituent of e. But this is not necessarily the case. The cookies could be eaten at some other time. For instance, they could be eaten in the locker-room after the game is over at some time t' preceding t_{u_2}. To be definite, consider the case where a previous utterance has established, by way of its impact, a speaker's connection to a time t' when the cookies were eaten. Then the described situation e' will be a situation different from the game e, and the propositional content of u_2 will be:

$$e' \models (\forall \dot{p})(\exists \dot{c}) \ll \text{eats}, \dot{p}, \dot{c}, t', 1 \gg$$

Whatever the described situation turns out to be, the two points to notice are, firstly, that the described situation may or may not provide the scope and resource situation for the quantified parameters, and secondly, the resource situation for an instance of the quantifier $(\exists \dot{c})$ is not necessarily the same as that for the instance of $(\forall \dot{p})$ to which it corresponds.

In the case where the cookies are eaten during the game, then the described situation provides the scope of the quantifier $(\forall \dot{p})$ and the resource situation for each anchor of $\dot{p}$ being a player in e. The described situation also provides the scopes for the quantifiers $(\exists \dot{c})$ and $(\exists \dot{t})$, but for neither of these quantifiers does it provide the appropriate resource situation.

If, on the other hand, the cookies are eaten at some other time determined by the speaker's connections associated with some prior utterance, then the described situation provides the scope for the quantifier $(\forall \dot{p})$ but not the resource situation for any anchor of $\dot{p}$ being a player in the game.

Thus, the theory places no restrictions on the possible scope of quantifiers or on the situations that can provide a resource for the anchor of a particular parameter. It is up to the speaker to ensure that the context of utterance provides the right connections to the scope of any quantifier and to the appropriate resource situations, where relevant. In the case of a cookie, this is clearly of little importance, at least in the majority of cases. But establishing the relevant game situation e and whether the cookies were eaten during the game or at some other time is critical to the success of the utterance as a conveyance of information. Situation semantics allows for, and reflects, all possibilities, but leaves the responsibility for effective communication where it belongs — with the speaker.

So far we have considered just two kinds of quantifiers, *for all* and *there exists*. In order to handle other quantifiers, some further development of the situation-theoretic framework is necessary.

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One solution is to enlarge the collection of compound infons by introducing various generalized quantifiers. For example, we could allow the following constructions to figure as compound infons:

$$(M\dot{x} \in u)\sigma \quad \text{and} \quad (F\dot{x} \in u)\sigma$$

where σ is a compound infon, where $(M\dot{x} \in u)$ denotes 'for most $\dot{x}$ in u', and where $(F\dot{x} \in u)$ denotes 'for few $\dot{x}$ in u'. Some form of definition of what these quantifiers actually mean would then be necessary of course.

An alternative approach is to regard quantifiers (at least those that arise explicitly in natural language) not as operators acting on infons, but rather as relations within the theory's ontology; in particular, as relations between types. Thus, for example, among the relations we might have the basic five-place relations $\forall, \exists, M, F$, and then the following would be infons:

$$\ll \forall, u, S, T, l, t, i \gg \quad \ll \exists, u, S, T, l, t, i \gg$$
$$\ll M, u, S, T, l, t, i \gg \quad \ll F, u, S, T, l, t, i \gg$$

where u is a set or situation and S and T are one-place types.

The first of these is the informational item that: if $i = 1$ then *all* objects in u of type S are of type T, and if $i = 0$ then it is not the case that all objects in u of type S are of type T (at location l and time t).

The second is the informational item that: if $i = 1$ then *there is* an object in u of type S that is of type T, and if $i = 0$ then there is no such object (at l, t).

The third is the information that: if $i = 1$ then *most* objects in u of type S are of type T, and if $i = 0$ then this is not the case (at l, t).

Finally, the fourth infon is the informational item that: if $i = 1$ then *few* objects in u of type S are of type T, and if $i = 0$ then this is not the case (at l, t).

Since quantification is now of the infonic form

$$\ll Q, u, S, T, l, t, i \gg$$

a situation is required in order to obtain a proposition

$$e \models \ll Q, u, S, T, l, t, i \gg$$

so the quantification is situated in, and hence restricted to, e.

Using this new framework, let's take a second look at the two previous examples. The first of these is an utterance u_1 of the sentence

$\Phi_1 :$ *Every player touched the ball.*

Under the new framework, the analysis of this utterance goes as follows. As before, the described situation, $s_{u_1}(\Phi_1)$, is the game, say g. Let S, T be the following object-types:

$$S = [\dot{p} \mid g \models \ll \text{player-in}, \dot{p}, g, 1 \gg]$$
$$T = [\dot{p} \mid g \models (\exists \dot{t}) \ll \text{touches}, \dot{p}, b, \dot{t}, 1 \gg]$$

where $\dot{p}$ is a parameter for a person, $\dot{t}$ is a parameter for a time prior to t_{u_1} and $b = c_{u_1}(\text{THE BALL})$. Then the propositional content of the utterance u_1 is:

$$g \models \ll \forall, g, S, T, 1 \gg$$

Notice that the use of the same parameter $\dot{p}$ in the two type-abstractions was in order to help the reader. In practice, since the abstraction parameter in a type-abstraction becomes 'absorbed', leaving solely an 'argument role', it does not matter which parameter is used in each abstraction. Rather, it is the nature of the relation $\forall$ that it links the argument roles of the two types.

One further remark that needs to be made at this juncture concerns the quantification of the time parameter $\dot{t}$ in the definition of the type T. This was done using the quantification mechanism for forming compound infons, rather than in terms of our new quantifier framework. This reflects the fact that an unarticulated quantification over time that arises by virtue of verb tense, is what might be called a 'structural' quantification. That is to say, verb tense mechanisms are part of the basic structure of language that our ontological framework is intended to handle: our ontology includes temporal locations and quantification over temporal locations in compound infons, and verb tense relates directly to this temporal aspect of our framework. Such implicit quantification is not at all the same as an articulated quantification, even one over time, such as an utterance u_1' of the sentence Φ_1':

> *Every player touched the ball many times.*

In this case, the analysis would be as follows.

Let M be a 'many' quantifier. Let T_b be the type

$$T_b = [\dot{t} \mid g \models \ll \text{touch}, \dot{p}, b, \dot{t}, 1 \gg]$$

where $\dot{t}$ is a parameter for a time prior to $t_{u_1'}$ and $\dot{p}$ is a parameter for a person. T_b is the parametric type of all instances at which some person touches b ($= c_{u_1'}(\text{THE BALL})$) during the course of the game g.

T_b is a parametric type with parameter $\dot{p}$, so we can form the type

$$T = [\dot{p} \mid g \models \ll M, g, TIM_1, T_b, 1 \gg]$$

the type of all persons for which there are many instances in g at which that person touches b. Then the propositional content of u_1' is:

$$g \models \ll \forall, g, S, T, 1 \gg$$

where S is as before.

Notice that the present framework allows for a quantifier such as 'for many' to be defined locally. In the case of the above example, the 'many' quantifier M could be specially tailored to ball games. This is a strong argument in favor of treating quantification as a relation within the ontology, rather than as part of the underlying framework. Indeed, we may use our framework to *investigate* such quantifiers.

The second of our two original examples is an utterance u_2 of

$\Phi_2 :$ *Every player ate a cookie.*

Let e be the described situation, $s_{u_2}(\Phi_2)$, whether this is the game g or some other situation. Let T_d be the type

$$T_d = [\dot{c} \mid e \models (\exists \dot{t}) \ll \text{eats}, \dot{p}, \dot{c}, \dot{t}, 1 \gg]$$

where $\dot{t}$ is a parameter for a time preceding t_{u_2}, $\dot{c}$ is a parameter for an edible individual, and $\dot{p}$ is a parameter for a person. Thus T_d is the type of all edible individuals that, in the situation e, are eaten at some time prior to t_{u_2} by some person. Noting that T_d is a parametric-type with parameter $\dot{p}$, let T_p be the type

$$T_p = [\dot{p} \mid e \models \ll \exists, e, T_c, T_d, 1 \gg]$$

where T_c is the type of a cookie. Thus T_p is the type of all those persons for which, in the situation e, there is a cookie eaten by that person at some time preceding t_{u_2}.

With S as before, the propositional content of u_2 is:

$$e \models \ll \forall, e, S, T_p, 1 \gg$$

The only question that remains to be answered is what is the described situation, e ? The naive answer is that e is simply the situation in which the cookies were eaten. But this does not work here, since the infon in the propositional content of the utterance involves the type S, which is an object-type with grounding situation g, and there is no reason to suppose that the situation in which the cookies were eaten supports an infon that concerns the game situation g. (If e and g coincide there is no problem. This is what happened with the previous

example concerning the players touching the ball many times.) So we must look further for our answer.

In fact, the resolution to the problem involves a shift in the way we regard quantification, since the approach we have adopted provides us with a view of quantification that more traditional definitions do not. Given that quantification is essentially a relation (indeed, a quantitative comparison) between two types, the utterance of any sentence involving a quantifier must be *about* those two types, among other things. That is to say, the described situation must include those two types.

Thus in the present example, the described situation, e, must include both the game situation, g, and the situation in which the cookies are eaten, say h. Then what the utterance does is describe a relation between the two situations g and h, namely the quantitative comparison between the individuals in g that are players and the individuals in h that ate a cookie. In this case, the fact that all individuals of the former type are of the latter type.

Notice that, although this was not the original aim, our investigation has led to an alternative conception of the nature of quantification: it is simply a particular kind of relation between types. Indeed, we can apply this to the 'traditional-style' quantifiers we allow in the formation of compound infons. Although our theory treats these quantifiers as logical operators on compound infons, we may apply our 'quantifiers-as-relations' conceptualization at a meta-theoretic level in order to regard these quantifiers as relations too.

Negation

There are a number of ways that a sentence can involve negation. The most straightforward of these is verb phrase negation. This is easily handled in situation semantics by means of a polarity change and a possible quantifier switch. For example, let u_1 be an utterance of the sentence

Φ_1 : *John did not see Mary.*

Let e be the described situation, $e = s_{u_1}(\Phi_1)$. Then the propositional content of u is

$$e \models (\forall \dot{t}) \ll \text{sees},\ J, M, \dot{t}, 0 \gg$$

where $\dot{t}$ is a parameter for a time prior to t_{u_1}, $J = c_{u_1}(\text{JOHN})$, and $M = c_{u_1}(\text{MARY})$.

There is, however, one question that needs to be answered. What is the described situation e? In the case of an utterance of the positive sentence *'John*

saw Mary' there is no problem. In the absence of any context that determined otherwise, the described situation will be the act of John seeing Mary, the situation in which the seeing takes place. In other words, for a positive utterance, in the absence of any other contextual features, the utterance itself determines the described situation. But for a negative utterance this is not the case. There will be a great many situations in which John did not see Mary. Just which one is the speaker referring to?

The answer is that it is up to the speaker to fix the described situation. At least, this is what the speaker's obligation amounts to in our theory's terms. In everyday language, what the speaker must do is ensure that the listener is aware just *what* the utterance is about. To make the utterance u_1 without having set the relevant context results in a failure to communicate. Uttered on its own, without there being either a predetermined described situation or else an obvious 'default' situation, the sentence Φ_1 does not convey information, at least not the information that would be captured by the propositional content. (Most obvious scenarios for such an utterance do in fact supply an obvious default described situation.)

Since there will be a great many situations in which John did not see Mary, in order for the utterance u_1 to convey the right information, the speaker must ensure that some aspect of the context of utterance determines the described situation e. The utterance should convey the same information, in the sense of propositional content, as an utterance of the 'sentence'

$$\sharp \ John \ did \ not \ see \ Mary \ in \ e$$

where the $\sharp$ indicates a sentence that is not part of normal English (in that one does not normally mention a situation).

The above remarks apply to a great many negative utterances. Of course, in the vast majority of cases the utterance of a positive sentence too is made with reference to a predetermined described situation. Speakers generally speak about some part of the world. Indeed, this is one of the main motivating factors behind situation theory.

Negated quantifiers are also handled quite easily. For example, let u_2 be an utterance of the sentence

$$\Phi_2 : \ Not \ every \ student \ passed \ the \ quiz.$$

Let $q = c_{u_2}(\textsc{quiz})$, let t_q be the time of taking the quiz q, and let e be the situation comprising the taking of the quiz.

Presumably the speaker is referring to some particular class, c, the class that took the quiz q. Let $\dot{p}$ be a parameter for a person, and let

$$S = [\dot{p} \mid c \models \ll \text{student-in}, \dot{p}, c, t_q, 1 \gg]$$
$$T = [\dot{p} \mid e \models \ll \text{passes}, \dot{p}, q, t_q, 1 \gg]$$

Then the propositional content of u_2 is:

$$d \models \ll \forall, c, S, T, 0 \gg$$

where d is the described situation.

Recalling the discussion of the previous section concerning quantifiers, note that the utterance states a relationship between the type of all students in c and the type of all persons who passed the quiz q, and accordingly the described situation d will extend both c, the grounding situation for type S, and e, the grounding situation for type T.

A seemingly more problematical form of negation is exemplified by an utterance, u_3, of the sentence

Φ_3 : *No sailors were there.*

Assuming u_3 is part of a discourse about a particular dinner party, say d, the natural assumption is that d is the described situation. In which case, how can a proposition of the form

$$d \models \sigma$$

have anything to say about sailors? There are no sailors at the party!

Clearly, it cannot. But a few moments reflection should indicate that this issue has nothing to do with negation. Consider an utterance, u_4, of the positive sentence

Φ_4 : *There is a sailor that was there.*

Though on this occasion a sailor will be a constituent of the party, it is unlikely that this situation will have anything to say about this particular person being a sailor, and so once again the propositional content cannot be of the form

$$d \models \sigma$$

So what has gone wrong?

The answer is that nothing is wrong, except for the assumption that d is the described situation for an utterance of Φ_3 or Φ_4. For both sentences involve quantifiers, and as we observed in the previous section, an utterance of a quantifier sentence states a relationship between two types, so the described situation must include the grounding situations of those two types.

Both u_3 and u_4 are about sailors: they describe a relation that connects the collection of all sailors and the dinner party d. The grounding situation for the type of all sailors is the world, or at least enough of the world to ground this type. So, if $\dot{t}$ is a parameter for a time preceding the utterance in each case, and if

$$S = [\dot{p} \mid w \models \ll \text{sailor}, \dot{p}, \dot{t}, 1 \gg]$$
$$T = [\dot{p} \mid d \models \ll \text{present-in}, \dot{p}, d, \dot{t}, 1 \gg]$$

then the propositional content of u_4 is

$$w \models (\exists \dot{t}) \ll \exists, d, S, T, \dot{t}, 1 \gg$$

and the propositional content of u_3 is

$$w \models (\forall \dot{t}) \ll \exists, d, S, T, \dot{t}, 0 \gg$$

(or possibly
$$w \models (\forall \dot{t}) \ll \text{No}, d, S, T, \dot{t}, 1 \gg$$

if the quantifier 'No' is regarded as a basic relation in the ontology).

Given our present conception of quantifiers then, even though u_3 or u_4 could be uttered as part of a discourse that until then had concerned the party situation exclusively, once the property of being a sailor is introduced, the so-called described situation is extended to include the grounding situation for being a sailor. Of course, you might object to my calling the resulting situation the *described situation* in this case, and look for another name. On the other hand, given a framework in which a quantifier is interpreted as a relation between two types, rather than some form of logical operator on the second of those types, which is the case in classical logic, then it really is the case that a quantifier utterance *describes* (some feature of) both those types (and hence their grounding situations in the case of object-types): indeed, it *compares* the two types.

It should be noted that the semantics assigned to u_4 is different from the semantics that would be assigned to an utterance u_4' (under the same circumstances and with reference to the same dinner party situation d) of the sentence:

A sailor was there.

In this case, the described situation is indeed the party, d, and the propositional content of the utterance is:

$$d \models \exists \dot{p} \exists \dot{t} \ll \text{present-in}, \dot{p}, d, \dot{t}, 1 \gg$$

where $\dot{p}$ is a parameter for a sailor and $\dot{t}$ is a parameter for a time prior to the time of utterance.

The distinction between u_4 and u_4' amounts to a difference in focus. Uttering the sentence

<p align="center">There is a sailor that was there</p>

makes a definite claim *about the collection of sailors* (namely that at least one of them was at the party). On the other hand, uttering the sentence

<p align="center">A sailor was there</p>

makes a claim *about the party* (namely that among the guests there was at least one sailor).

Of course, none of the above examples involves a *negation* in the sense of classical logic, where negation is a logical operator that acts on well-formed formulas. Rather they are simply utterances of sentences that involve a negative component. As we have seen, this generally requires more emphasis on the specification of the described situation than is the case for utterances where there is no such negative component, but apart from that there was no real difference between positive and negative assertions as far as the above analysis was concerned.

Far more reminiscent of the negation operator of classical logic is sentence *denial*, where a positive assertive sentence is prefixed by a phrase such as 'It is not the case that ...' For example, let u_5 be an utterance of the sentence

Φ_5 : *It is not the case that John saw Mary.*

The starting point of most discussions is to take the phrase *'It is not the case that'* as determining a denial operator that acts on the sentence *'John saw Mary'*. Situation semantics takes a different tack, regarding Φ_5 as a negative version of the sentence

Φ_6 : *It is the case that John saw Mary.*

In both cases, let J be the referent for the name JOHN, M the referent for the name MARY, $\dot{t}$ a parameter for a time prior to the time of utterance.

Let $e_5 = s_{u_5}(\Phi_5)$, $e_6 = s_{u_6}(\Phi_6)$.

The propositional content of u_6 is:

$$w \models \ll \models, e_6, (\exists \dot{t}) \ll \text{sees}, J, M, \dot{t}, 1 \gg, 1 \gg$$

That is to say, the effect of the prefix *'It is the case that'* in an utterance of a sentence *'It is the case that* Φ*'* is to make the propositional content of the sub-utterance of Φ the infon part of a proposition about the world.

Turning now to u_5, the most natural choice of the propositional content would seem to be:

$$w \models \ll \models, e_5, (\exists \dot{t}) \ll \text{sees}, J, M, \dot{t}, 1 \gg, 0 \gg$$

where the polarity of the world proposition has changed from a 1 in the case of u_6 to a 0 in the case of u_5. Does this accord with our intuitions?

Unravelling the notation a bit, what this proposition says is that

$$(*) \qquad e_5 \not\models (\exists \dot{t}) \ll \text{sees}, J, M, \dot{t}, 1 \gg$$

Now, in order for a negative utterance to be informational (in the intended manner), the speaker should ensure that the described situation is adequately identified. That is to say, the speaker should make sure that the listener knows what the utterance is *about.* In the present case, e_5 is the John and Mary situation, or something extending it. Since John's seeing Mary is a relevant feature (the speaker talks about it), it ought to be the case that the situation e_5 that constitutes the described situation completely determines whether or not John actually did see Mary or not. That is to say, it should be the case that: either

$$e_5 \models (\exists \dot{t}) \ll \text{sees}, J, M, \dot{t}, 1 \gg$$

or else

$$e_5 \models (\forall \dot{t}) \ll \text{sees}, J, M, \dot{t}, 0 \gg$$

Assuming this is the case, then by $(*)$, the propositional content of u_5 should entail the second of these two propositions. This is what we would have expected.

Notice that the above places a restriction on the possible described situation for utterances involving denials. The requirement we have stipulated is considerably stronger than the universally true fact that for any situation s and any infon σ, either $s \models \sigma$ or else $s \not\models \sigma$. A cooperative use of a negative utterance such as u_5 places on the speaker an obligation to ensure that the described situation as understood by the listener (i.e. *what* the listener thinks the utterance is *about*) is sufficiently rich to *decide* the relevant issue, in this case whether John saw Mary or not, one way or the other.

A natural question to ask in connection with sentence denial is how it affects conjunctive and disjunctive sentences. The natural expectation is that there is some form of duality between the two, as occurs in classical logic. And indeed this is the case, given that certain requirements are met.

For example, imagine a discourse between Jan and Ed about last week's 49ers game, g, in which Jan makes the following utterance, u:

It is not the case that Joe threw the ball and Roger carried the ball.

This has a propositional content of the form

$$w \models \ll \models, g, \sigma, 0 \gg$$

where σ is the compound infon

$$(\exists \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 1 \gg \wedge (\exists \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 1 \gg$$

and where $J = c_u(\text{JOE})$, $R = c_u(\text{ROGER})$, and $b = c_u(\text{THE BALL})$.

Unravelling the notation a little, this says the following:

$$(*) \quad g \not\models (\exists \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 1 \gg \wedge (\exists \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 1 \gg$$

Now, since g is the actual game, either

$$g \models (\exists \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 1 \gg$$

or else

$$g \models (\forall \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 0 \gg$$

and again either

$$g \models (\exists \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 1 \gg$$

or else

$$g \models (\forall \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 0 \gg$$

So by $(*)$ it must be the case that at least one of

$$g \models (\forall \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 0 \gg$$

and

$$g \models (\forall \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 0 \gg$$

Hence

$$g \models (\forall \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 0 \gg \vee (\forall \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 0 \gg$$

Reverting back to infon notation, this becomes

$$w \models \ll \models, g, \overline{\sigma}, 1 \gg$$

where $\overline{\sigma}$ is the compound infon

$$(\forall \dot{t}_1) \ll \text{throws}, J, b, \dot{t}_1, 0 \gg \vee (\forall \dot{t}_2) \ll \text{carries}, R, b, \dot{t}_2, 0 \gg$$

In words:

> *It is the case that Joe did not throw the ball or Roger did not carry the ball.*

Which seems right.

The above example is related to the following notion of *infon duality*, which is important in studies of compositionality.

The *dual*, $\overline{\sigma}$, of a compound infon, σ, is defined by recursion as follows.

- If σ is a basic infon of the form $\ll R, a_1, \ldots, a_n, i \gg$ then

$$\overline{\sigma} = \ll R, a_1, \ldots, a_n, 1 - i \gg$$

- If $\sigma = \sigma_1 \wedge \sigma_2$, then $\overline{\sigma} = \overline{\sigma_1} \vee \overline{\sigma_2}$

- If $\sigma = \sigma_1 \vee \sigma_2$, then $\overline{\sigma} = \overline{\sigma_1} \wedge \overline{\sigma_2}$

- If $\sigma = (\forall \dot{x} \in u)\tau$, then $\overline{\sigma} = (\exists \dot{x} \in u)\overline{\tau}$

- If $\sigma = (\exists \dot{x} \in u)\tau$, then $\overline{\sigma} = (\forall \dot{x} \in u)\overline{\tau}$

We say a situation e is *complete* relative to the compound infon σ if at least (and hence exactly) one of the propositions

$$e \models \sigma \quad , \quad e \models \overline{\sigma}$$

is valid.

A generalization of the above argument shows that if u is an utterance of a denial

It is not the case that Φ

and if the sub-utterance of the sentence Φ has the propositional content

$$e \models \sigma$$

and if e is complete relative to σ, then the propositional content of u is

$$w \models \ll \models, e, \overline{\sigma}, 1 \gg$$

which is 'equivalent' to

$$e \models \overline{\sigma}$$

The point made earlier is that, for an utterance of a denial to be suitably informational, the speaker should ensure that the listener is sufficiently aware of the context. In the theory's terms, what this amounts to is that the described situation as understood by both speaker and listener should be complete relative to the requisite infon.

Conditionals

Conditionals, or *if–then* statements, are the bedrock of rational argument and as such are central not only to such overtly 'logical' pursuits as mathematics, computer science, the sciences in general, philosophy, and the legal system, but to large parts of our everyday life. And yet for all their ubiquity, conditionals resisted the attempts of generations of philosophers to understand just what the devil they *are*? What exactly does a conditional say about the world? There is a great deal that can, and has been, said. Here we shall simply pursue the matter sufficiently to indicate the role that situation theory can play.

In our current terminology, the issue to be investigated is this. If u is an utterance of a conditional of the form

$$\textit{If } \Phi \textit{ then } \Psi$$

then what is the propositional content of u (and hence what is the meaning of the sentence uttered)?

We consider four examples that, though having some similarities, lead to quite different, but in many ways paradigmatic analyses:

1. *If it freezes, Ovett wears a hat.*

2. *If it freezes, Ovett will not run.*

3. *If it freezes, Ovett will be cold.*

4. *If it had frozen, Ovett would not have run.*

Again as a homage to the era when situation semantics was being developed, all four examples will be understood to refer to cross-country races and the British athlete Steve Ovett, who dominated middle distance running in the 1980s.

Sentence 1 appears first because its analysis turns out to be different from the others. Indeed, although all four sentences have an *if–then* form, an utterance of any of sentences 2, 3, or 4 will refer to a specific, single event, a cross-country race in this case, whereas sentence 1 can only be used to refer to such events *in general*.

In fact, an utterance of sentence 1 does not express a *conditional* at all, but rather is a statement of the validity of a certain constraint, a general connection the obtains between all those events when it freezes and all those events when Ovett wears a hat. (Actually, there is a reading of sentence 2 that also serves to express a general link. We shall not consider this alternative reading, and the analysis presented below will exclude this possibility. As always, the main

concern is with utterances of sentences, and by concentrating on utterances we avoid alternative readings of sentences.)

The remaining three sentences all do express genuine conditionals of one form or another. Sentences 2 and 3 are syntactically similar. Each may be used to predict some form of link between two specific future events. Sentence 4 is different in that a speaker would normally only utter sentence 4 after the race in question had taken place, and moreover only if, counter to the antecedent of the utterance, it had in fact not frozen. Statements made with sentences such as 4, where the antecedent is false, are known as *counterfactuals*. Non-counterfactual, predictive-type conditionals such as examples 2 and 3 are often referred to as *indicative* conditionals.

Let u_1 be an utterance of sentence 1:

> *If it freezes, Ovett wears a hat.*

This does not refer to any particular pair of events. Rather the utterance states that there is a connection between two *types* of event, the type of race situation where it is freezing and the type of race situation where Ovett wears a hat. In other words, what u_1 does is state a certain constraint. We make this precise below.

Let

$$S = [\dot{e} \mid \dot{e} \models \ll \text{present-in}, SO, \dot{e}, \dot{t}_r, 1 \gg$$
$$\wedge \ll \text{registered-in}, SO, \dot{r}, \dot{t}_r, 1 \gg$$
$$\wedge \ll \text{freezing}, \dot{t}_r, 1 \gg]$$

$$T = [\dot{e} \mid \dot{e} \models \ll \text{wears-hat}, SO, \dot{t}_r, 1 \gg]$$

where $\dot{r}$ is a parameter for a race, $\dot{e}$ is a parameter for the situation surrounding $\dot{r}$ (that is to say, the race itself, the race organization, and the environment local to the race), $\dot{t}_r$ is a parameter for the time of $\dot{r}$, and $SO = c_{u_1}(\text{OVETT})$.

Then the propositional content of u_1 is

$$w \models (S \Rightarrow T)$$

or at least

$$d \models (S \Rightarrow T)$$

for a suitably large part of the world d (enough to include all the race situations involving Steve Ovett).

The remaining three examples all have in common the fact that they are used to refer to specific events. (At least, this is true in the case of their normal uses,

the ones considered here.) Nevertheless they all exhibit quite distinctive features that make it difficult to come up with any kind of unified treatment that seems appropriate for all examples.

We shall present two alternative treatments, both of which have some appeal as well as some shortcomings.

One approach to handling conditionals in logic is the material conditional. The first treatment of the semantics of sentences 2 through 4 develops a version of this approach within the framework of situation semantics. (This treatment adopts an extreme form of the material conditional that expresses nothing more than the contingent prohibition of two particular eventualities. Other treatments of the conditional can be developed within the framework of situation theory that could also be described as a material conditional — for example, taking the relationship to link *types* rather than specific propositions as below.)

Let u_2 be an utterance of sentence 2:

If it freezes, Ovett will not run.

A situation-theoretic analysis of this utterance along the lines of the material conditional goes as follows.

The utterance u_2 refers to some particular circumstance, an upcoming race and how the weather will affect the participation of Ovett. The described situation, d, therefore, comprises the organization of the race and the meteorological environment local to the race.

Note that the race is not an existing situation, nor an event that has taken place in the past, but rather is some planned, future event: indeed an event that might eventually be cancelled, and not take place at all. Thus r has an objective existence purely as a result of the intentionality network of planning agents, *to whit* Man. But this does not prevent r being a perfectly well-defined situation in our ontology. People discuss future events all the time, and frequently plan their activities around future events.

What claim does the utterance make about the situation d? It does not state some kind of constraint, as does an utterance of 1. Nor is there a constraint of which this is an instance, as is the case in example 3, which we consider presently. There is no generally prevailing causal link between the local temperature and Ovett running or not running. Runners can, and do, run in freezing conditions, Ovett among them. The freezing conditions might well be the *reason* Ovett decides not to run on this particular occasion, but that is Ovett's personal decision. There is no general rule, no constraint as there was in example 1.

Rather what the utterance does is claim that a certain event will not occur, namely the event of it freezing and Ovett running in the race. That is to say, if

we let r be the race, l_r the location of r, t_r the time of r, and e the environment local to l_r, then the propositional content of u_2 is:

$$d \models \ll \text{precluded}, P \wedge Q, t_u, 1 \gg$$

where P is the proposition

$$e \models \ll \text{freezing}, l_r, t_r, 1 \gg$$

and Q is the proposition

$$r \models \ll \text{runs-in}, SO, r, t_r, 1 \gg$$

and where $SO = c_{u_2}(\text{OVETT})$.

Turning now to sentence 3, let u_3 be an utterance of :

If it freezes, Ovett will be cold.

Again we develop a situation-theoretic analysis analogous to the material conditional of classical logic.

In this case the utterance u_3 expresses an instance of a general *constraint*, the constraint that if it is freezing then a person will be cold. There is a definite, generally prevailing, causal link between the antecedent *'it freezes'* and the consequent *'Ovett will be cold'*. However, it is arguable (see momentarily) that although 2 and 3 differ as to the reason for the validity of the expressed conditional, this difference does not affect the meaning of the sentence, and the propositional content in the case of example 3 will be just as in 2. Thus, if d is the described situation and t_d is the requisite time (so $t_d = c_{u_3}(\text{WILL})$ and $t_{u_3} \prec t_d$), then the propositional content of the sub-utterance of *'it freezes'* is

$$d \models \ll \text{freezing}, t_d, 1 \gg$$

and the propositional content of the sub-utterance of *'Ovett will be cold'* is

$$d \models \ll \text{cold}, SO, t_d, 1 \gg$$

Then the propositional content of u_3 is

$$d \models \ll \text{precluded}, P \wedge Q, t_{u_2}, 1 \gg$$

where P is the proposition

$$d \models \ll \text{freezing}, t_d, 1 \gg$$

and Q is the proposition

$$d \models \ll \text{cold}, SO, t_d, 0 \gg$$

According to the above analysis then, the reason why the semantics of 3 works out the same as for 2 is that, although the utterance of 3 states an instance of a general constraint, it is not part of the utterance that it is such an instance. Rather the utterance asserts a simple conditional that expresses, as a matter of fact, that a particular pair of events cannot occur in conjunction. The distinction between 2 and 3 is part of the general background knowledge of the world that both the speaker and listener will be aware of. The constraint of which 3 states a particular instance is not part of the propositional content of the utterance u_3, since the utterance makes no reference to the constraint.

So far then, a material-conditional style analysis seemed to work for examples 2 and 3. What about the final example? Let u_4 be an utterance of the sentence 4:

If it had frozen, Ovett would not have run.

Presumably u_4 refers to a specific event, a past race r, run at a location l_r at a time t_r where $t_r \prec t_u$, in an environment e. The utterance refers to properties of each of the situations r and e, the property of it freezing in e and the property of Ovett running in r. This was also the case in example 2. If we attempt an analysis using the material-conditional approach as in example 2, we obtain the following propositional content for u_4:

$$d \models \ll \text{precluded}, P \wedge Q, t_u, 1 \gg$$

where P is the proposition

$$e \models \ll \text{freezing}, l_r, t_r, 1 \gg$$

and Q is the proposition

$$r \models \ll \text{runs-in}, SO, r, t_r, 1 \gg$$

and where d is the described situation.

But what is the described situation? In the case of example 2, d comprised both r and e, that is to say, both the race and the (meteorological) environment local to the race. But this cannot be right in this case. Why? Well, the use of the subjunctive in 4 is only appropriate if in fact

$$e \models \ll \text{freezing}, l_r, t_r, 0 \gg$$

and if this is the case and we take d to extend e, then our proposed propositional content is degenerate and essentially non-informational: it would be a valid proposition regardless of whether or not Ovett ran in the race.

This is, of course, why the material conditional fails so miserably to handle counterfactuals in classical logic. The material conditional renders a proposition

$$P \to Q$$

as true whenever P is false, and consequently is unable to handle counterfactuals, which by their very nature have a false antecedent.

But a situation-theoretic framework saves us from falling into this trap, and in a way that squares with our everyday intuitions about counterfactuals. In making an utterance of 4 with the sincere intention of conveying information, the speaker is not referring to the situation as it was, but to some hypothetical variant thereof, a variant that resembles the actual situation in almost every way except for differing as to the fact of it freezing or not.

In other words, the described situation d is not a part of the world extending the actual race-environment situation e. It is some abstract situation postulated by the speaker. If d_a denotes the actual race organization and environment local to the race, what was the described situation in example 2, then d and d_a will have the same constituents and the same spatial and temporal extent, and for almost all infons σ it will be the case that

$$d \models \sigma \quad \text{if and only if} \quad d_a \models \sigma$$

but

$$d \models \ll\text{freezing}, l_r, t_r, 1 \gg \quad \text{and} \quad d_a \models \ll\text{freezing}, l_r, t_r, 0 \gg$$

What justification is there for allowing a situation such as d into the ontology? Well, people do indeed use conditionals such as the above all the time, and if you accept the two premises that (a) when two people are engaged in a successful exchange of information, they must be talking about *something*, and (b) we use situations to represent these 'somethings', then it follows that hypothetical entities such as the d above will figure as situations.

To summarize the above account, suppose u is an utterance of a conditional sentence of the form

$$\textit{If } \Phi \textit{ then } \Psi$$

(or equivalent) and that

$$e_1 \models \sigma_1$$

is the propositional content of the sub-utterance of Φ and

$$e_2 \models \sigma_2$$

is the propositional content of the sub-utterance of Ψ. Then the propositional content of u is:

$$d \models \ll \text{precluded}, (e_1 \models \sigma_1) \wedge (e_2 \models \overline{\sigma_2}), t_u, 1 \gg$$

where $d = s_u(\text{IF } \Phi \text{ THEN } \Psi)$ is the described situation.

In the case of an indicative conditional, the described situation, d, will include both e_1 and e_2. In the case of a counterfactual, where in fact

$$e_1 \models \overline{\sigma_1}$$

then d will be a hypothetical situation that differs minimally from what actually occurred (i.e. from a situation including both e_1 and e_2) in that:

$$d \models \sigma_1$$

The alternative approach to the semantics of conditionals is not only uniform across examples of forms 2, 3, and 4, as was the case with the first treatment, but in fact includes example 1 as well, in that an utterance of *any 'if–then'* statement is taken to refer to a constraint (in one way or another).

We commence with sentence 3. As before, u_3 is an utterance of the sentence

If it freezes, Ovett will be cold.

This utterance expresses an instance of the constraint that, if a person's environment is freezing, and that person is scantily clad (such as a runner), then that person will be cold. More precisely, let S and T be the situation-types

$$S = [\dot{e} \mid \dot{e} \models \ll \text{freezing}, \dot{t}, 1 \gg$$
$$\wedge \ll \text{present-in}, \dot{p}, \dot{e}, \dot{t}, 1 \gg$$
$$\wedge \ll \text{scantily-clad}, \dot{p}, \dot{t}, 1 \gg]$$
$$T = [\dot{e} \mid \dot{e} \models \ll \text{cold}, \dot{p}, \dot{t}, 1 \gg]$$

where $\dot{e}$ is a situation parameter, $\dot{t}$ is a temporal parameter, and $\dot{p}$ is a parameter for a person.

Then the described situation for u_3 is the world and the propositional content is:

$$w \models (S \Rightarrow T)[f]$$

where f anchors $\dot{p}$ to $SO = c_{u_3}(\text{OVETT})$.

Turing now to example 2, let u_2 be an utterance of the sentence:

If it freezes, Ovett will not run.

As noted earlier, u_2 differs from u_3 in that it does not express an instance of a general constraint. And yet it does make a *prediction* of a future event. Assuming this prediction has an informational basis, and is not just a random guess, how can this be? Surely the only informational basis on which to make such a prediction is knowledge of some uniformity that systematically links the eventuality of it freezing and Ovett's deciding not to run; in other words, a constraint.

But what constraint? As observed earlier, runners can and do run in freezing conditions. Indeed, Ovett himself has run in freezing conditions, though as a matter of fact he prefers not to. Whether or not Ovett runs in the race referred to in the utterance u_2 is purely up to Ovett to *decide*. So where is the constraint?

The answer is that human beings are *planning* creatures. They form plans or intentions as to their future courses of action. And part of this plan-formation process will involve establishing what we might call *personal constraints*, constraints that govern their own action in accordance with their own desires and intentions.

Thus, Ovett, having found as a result of past experience that running in freezing conditions is unpleasant, and indeed can lead to illness and injury, might well decide that in future he will not run if it is freezing. Or it may be even more specific than this. Maybe he has just recovered from a cold and decides that, as far as next Saturday's race is concerned, the one referred to in u_2, he will not run if it is freezing. Beyond next Saturday he forms no intentions either way as far as running in cold weather is concerned. But for this one occasion he forms a personal constraint that will guide his future actions.

Knowing of this constraint, a speaker may then confidently utter sentence 2. That is to say, it is the knowledge of the constraint that provides the speaker with an informational basis for the utterance. In effect, what the utterance of sentence 2 conveys to the listener is that 'this guy Ovett has formed the intention that *if* it is freezing on the day of this particular race, *then* he will not run'. Indeed, we may adopt the position that it is precisely this constraint that provides the propositional content of u_2.

More precisely, let S and T be the situation-types

$$S = [\dot{e} \mid \dot{e} \models \ll \text{environment-of}, \dot{e}, r, t_r, 1 \gg$$
$$\wedge \ll \text{freezing}, l_r, t_r, 1 \gg]$$
$$T = [\dot{e} \mid \dot{e} \models \ll \text{run-in}, SO, r, l_r, t_r, 0 \gg]$$

where r is the race in question, l_r is its location, t_r is its time, and $\dot{e}$ is a situation parameter.

Taking the described situation, d, to be Ovett's state at the temporal interval t_{u_2}) then the propositional content of u_2 is:

$$d \models (S \Rightarrow T)$$

At which point a not unnatural question would be: why does the same treatment not work in the case of sentence 3? Though in the case of 3 there was a prevailing general constraint, the actual utterance only referred to an instance of that constraint involving Ovett. So why in case 3 did we take the described situation to be the world, and the propositional content to be

$$w \models (S \Rightarrow T)[f]$$

where $(S \Rightarrow T)$ is a general constraint and f an anchor to Ovett? Why not particularize the constraint to Ovett in the first place, as in example 2?

The answer is this. In case 2, the utterance has nothing to do with Ovett's state of mind, with his desires and his intentions. There is no personal constraint of this nature. For all the speaker or listener knows, Ovett has not given a thought to it being cold on race day and his getting cold then. Moreover, there is no reason to assume that the situation d will support the general constraint that if it is freezing a person will get cold, or even that if it is freezing Ovett will get cold. Nevertheless, if it does freeze on race day, Ovett certainly will get cold. Not because of any plan of intention he has formed. Simply because there is a prevailing general constraint to the effect that scantily clad people get cold if the temperature falls below freezing. The propositional content of u_3 has a structure that accords with this observation.

In example 2, on the other hand, there is no prevailing general constraint, only the personal constraint (or 'contingency plan') formulated by Ovett.

In neither case does the speaker explicitly mention the constraint. But, according to the present account, the constraint is nevertheless the *content* of the utterance: the propositional content captures what it is the speaker claims to be the case.

Finally, what about the counterfactual case, example 4? Let u_4 be an utterance of the sentence

If it had frozen, Ovett would not have run.

The grammatical structure of the sentence makes it clear that the utterance is made after the race has taken place, and that in fact it had not frozen. The speaker is describing the personal constraint Ovett had formed prior to the race. As it happens, the conditions that would have brought that constraint into play, and resulted in Ovett's not running, did not prevail — it did not freeze. But Ovett

nevertheless *had formed* that constraint, and would have acted in accordance with it. This is what the utterance claims. Accordingly, the propositional content of the utterance is almost the same as in the previous case.

What distinguishes these two cases are the circumstances of utterance. In example 2, at the time of the utterance, the race has not yet taken place ($t_u \prec t_r$) and the utterance describes a constraint that prevails at the time of utterance; in example 4, the race has already taken place ($t_r \prec t_u$) and moreover it did not freeze, and the utterance describes a constraint that prevailed at the time of the race. Thus with the types S and T as before, the propositional content of u_4 is

$$d \models (S \Rightarrow T)$$

where in this case the described situation, d, is Ovett's state *at the time of the race*.

We finish this section by examining a famous pair of examples due to Quine. The traditional question is what is the status of the following two sentences?

(1) *If Bizet and Verdi had been compatriots, Bizet would have been Italian.*

(2) *If Bizet and Verdi had been compatriots, Verdi would have been French.*

A lot of the considerable discussion generated by these examples has concentrated on their counterfactual nature. But similar problems arise if we consider the following two indicative sentences involving the contemporary American philosopher John Perry and the British linguist Robin Cooper:

(3) *If Perry and Cooper are compatriots, then Perry is English.*

(4) *If Perry and Cooper are compatriots, then Cooper is American.*

We investigate both pairs of sentences first using the material conditional framework and then in terms of the constraint-based approach. The conclusion we shall draw is that the material conditional works moderately well in the case of sentences (1) and (2), but fails hopelessly when presented with (3) and (4), whereas the treatment in terms of constaints handles both pairs with ease. Indeed, my examination of these examples provides strong evidence to suggest that the constraint-based approach is the right way to handle conditionals, be they counterfactual or indicative.

Of course, unlike many of the discussions that have taken place concerning sentences (1) and (2), our approach will be in terms of utterances of these sentences. So, starting with the material conditional treatment of the first pair of sentences, let u_1 be an utterance of sentence (1). Let $B = c_{u_1}(\text{BIZET})$, $V = c_{u_1}(\text{VERDI})$, and let t be the time to which the utterance implicitly refers, i.e. the time when both Bizet and Verdi were alive. Let d denote the described situation.

According to the framework developed above, the propositional content works out to be:

(i) $d \models \ll \text{precluded}, P \wedge Q, t_{u_1}, 1 \gg$

where P is the proposition

(ii) $d \models \ll \text{compatriots}, B, V, t, 1 \gg$

and Q is the proposition

(iii) $d \models \ll \text{Italian}, B, t, 0 \gg$

and where d differs from reality, d_a, in a minimal fashion such that (ii) is valid.

Now,

(iv) $d_a \models \ll \text{Italian}, V, t, 1 \gg$

and

(v) $d_a \models \ll \text{French}, B, t, 1 \gg$

So if d is to differ from d_a minimally it must, by (i), be the case that

(vi) $d \models \ll \text{Italian}, V, t, 1 \gg$

and

(vii) $d \models \ll \text{Italian}, B, t, 1 \gg$

Thus in this case d is a hypothetical situation in which both Bizet and Verdi are Italian.

Starting with an utterance u_2 of sentence (2) we likewise end up with a hypothetical situation d' such that

(viii) $d' \models \ll \text{French}, V, t, 1 \gg$

and

(ix) $d' \models \ll \text{French}, B, t, 1 \gg$

These are the only possible outcomes if the described situation is to differ *minimally* from reality.

Is this a reasonable account? Although it does provide a consistent semantics of utterances of sentences (1) and (2), you may not find it particularly convincing. But still, it is a solution.

On the other hand, as far as the second pair of examples is concerned, utterances of sentences (3) and (4), the material conditional approach simply does not get off the ground. An utterance of either (3) or (4) certainly does not postulate a hypothetical, alternative world the way that the subjunctive in (1) and (2) does. Rather the described situation must be (part of) the real world. But then the falsity of the antecedent renders the entire semantics degenerate.

Ultimately, it is this example, and others like it, that persuade many to opt for the second of my two treatments, the one in which conditionals are taken to refer to constraints, even though the material conditional does provide a good semantics for the future-directed, predictive type of indicative conditional and an acceptable, if not wholly convincing, semantics for counterfactuals.

The constraint-based semantics for conditionals provides a uniform treatment for all four sentences, as well as clarifying the issues involved in these examples.

An utterance of any one of the four sentences refers to a generally prevailing constraint of the form:

> *If person A and person B are compatriots and person A has nationality N, then person B has nationality N.*

for some nationality N.

Let u_1 be an utterance of sentence (1), and let B, V, t denote Bizet, Verdi, and the time they were both alive, as before. Let $\dot{a}, \dot{b}$ be parameters for people, and let S_1, T_1 be the situation-types

$$S_1 = [\dot{e} \mid \dot{e} \models \ll\text{compatriots}, \dot{a}, \dot{b}, \dot{t}, 1 \gg \wedge \ll\text{Italian}, \dot{a}, \dot{t}, 1 \gg]$$

$$T_1 = [\dot{e} \mid \dot{e} \models \ll\text{Italian}, \dot{b}, \dot{t}, 1 \gg]$$

Then the described situation for u_1 is the world and the propositional content of u_1 is:

$$w \models (S_1 \Rightarrow T_1)[f]$$

where $f(\dot{a}) = V, f(\dot{b}) = B$.

Similarly, the propositional content of an utterance, u_2, of sentence (2) is:

$$w \models (S_2 \Rightarrow T_2)[f]$$

where

$$S_2 = [\dot{e} \mid \dot{e} \models \ll\text{compatriots}, \dot{a}, \dot{b}, \dot{t}, 1 \gg \wedge \ll\text{French}, \dot{b}, \dot{t}, 1 \gg]$$

$$T_2 = [\dot{e} \mid \dot{e} \models \ll\text{French}, \dot{a}, \dot{t}, 1 \gg]$$

and where f is as before.

Notice that this semantics for utterances u_1 and u_2 resolves the confusion that can arise between (1) and (2). Given the constraint that figures in its propositional content, an utterance of sentence (1) will be appropriate — that is to say it will be informational — if the listener and speaker know that Verdi was Italian. Then the utterance makes a valid assertion that describes this particular instance of that constraint. Likewise, an utterance of u_2 will be appropriate given the knowledge that Bizet was French.

Of course, an anchor, f, that assigns Verdi to the parameter $\dot{a}$ and Bizet to the parameter $\dot{b}$ is not possible for any situation that includes both of these individuals and is of type S_1, so there can be no actual situation to which the constraint

$$(S_1 \Rightarrow T_1)[f]$$

applies.

If you accept the existence of hypothetical situations, then this is not an obstacle. Since the constraint is reflexive, it simply guarantees that in any hypothetical situation e in which Bizet and Verdi are compatriots and Verdi is Italian, then Bizet is Italian.

However, even if you reject hypothetical situations, the propositional content is still informational, in that it describes a valid constraint: the constraint itself is not invalid, it is just that it does not apply to the pair Bizet, Verdi.

Similar remarks apply in the case of the second sentence.

Turning now to the pair (3), (4), all we need to do now is observe that the above analysis works equally well in this case. Indeed, the temporal location plays no external role in the above discussion, and hence there is no distinction between the first pair and the second as far as our analysis is concerned. It applies equally to sentences that refer to past events and sentences that apply to the present, and indeed to sentences that refer to the future.

The Liar Paradox

To finish, we see how situation semantics resolves the famous semantic paradox, the Liar. This is most often given as a query for the truth or falsity of the sentence:

(1)   *This sentence is false.*

In this form, the problem does not arise for us, since sentences are not the kinds of object that are either true or false. Instead, they are objects that can be *used* to convey information. Since a sentence is not an appropriate argument for the property 'true/false', from a situation semantic perspective (1) simply has no meaning.

Suppose we modify the question to the truth or falsity of an *utterance* of the sentence:

(2)   *This utterance is false.*

Again there is no paradox: this sentence too has no meaning. As with sentences, utterances are not the kinds of things that are true or false. However, we are getting closer, since an utterance of an assertive sentence will determine a *proposition*, and in situation semantics it is the propositions that are the bearers of truth.

The correct formulation of the Liar paradox in situation semantics is in terms of the proposition determined by an utterance, u, of the sentence:

(3)   *The proposition expressed by this utterance is false*

or, more simply but less precise, an utterance of the sentence

(Φ)   *This proposition is false.*

Let s be the described situation, $s = s_u(\Phi)$. Then, taking the basic property here to be *'true'*, with *'false'* being identified with *'not true'*, the propositional content, p, of u is:
$$s \models \ll \text{true}, p, 0 \gg$$
Notice that p is itself the proposition referred to by the phrase THIS PROPOSITION in the utterance, that is:

$$p = c_u(\text{THIS PROPOSITION})$$

The utterance claims that p is false. In other words, p claims that p is false. This is starting to look like a paradox. But we need to make sure we know exactly what is meant by 'false' here. Since we are taking *'false'* to mean *'not true'*, this amounts to clarifying what we mean by 'truth'.

In situation semantics, every proposition

$$e \models \sigma$$

is either *true* or *false* (i.e. *not true*). Truth means that e does indeed support σ, which is a strong condition to place on the situation s. Falsity, on the other hand, means simply that s fails to support σ, which is fairly weak — unlike the proposition $e \models \overline{\sigma}$, which is strong, but in general quite different. Let's examine the proposition p above with this notion firmly in mind.

Suppose first that p is true. Thus

$$s \models \ll \text{true}, p, 0 \gg$$

is a valid proposition. Then, since s is part of the entire world, w, it follows that

$$w \models \ll \text{true}, p, 0 \gg$$

is a valid proposition. In other words, p is false. This is a contradiction.

Hence p must be false. In other words,

$$s \not\models \ll \text{true}, p, 0 \gg$$

But this is not necessarily a paradox. All it says is that the situation s does not support the infon

$$\ll \text{true}, p, 0 \gg$$

Now since p is false, we certainly have

$$w \models \ll \text{true}, p, 0 \gg$$

but again this is not necessarily paradoxical unless $s = w$. So what our investigation amounts to is not a paradox but a straightforward proof of a theorem:

Theorem 1: $s_u(\Phi) \neq w$

In words, the described situation in an utterance of the Liar sentence Φ cannot be the world.

Moreover, since we have shown that p is false, we have also established another theorem:

Theorem 2: Any utterance of the Liar sentence Φ expresses a false proposition.

In short, the Liar paradox has been resolved. Or has it? Can't we simply re-introduce the paradox by modifying Φ to read:

(Φ')   *This proposition is false in the world*

Surely in this case the described situation, $s_u(\Phi')$, will have to be $w = c_u(\text{THE WORLD})$, won't it?

In fact it will not. Analogs of Theorems 1 and 2 go through for the modified sentence Φ', so the same argument as before shows that w cannot be the described situation.

The conclusion has to be that w is *not* a situation. And so we have a third theorem:

Theorem 3: w is not a situation.

This is analogous to the result in set theory that the class of all sets is not a set. But notice that this does not prevent set-theorists from discussing the so-called *universe* of sets, V, all the time, and often treating it as if it were a set. The trick is simply to develop enough sophistication to do this with safety.

Similarly, in situation theory we often handle *the world* much as if it were a situation. We just have to bear in mind that it is not in fact a situation, and make sure we do not use it inappropriately.

Further reading

For a historical introduction to the early development of situation semantics, see Barwise and Perry's initial 1980 paper [3] and their 1983 book [4].

For a comprehensive coverage of situation theory and situation semantics as it eventually settled down, see Devlin's 1991 book [6]. Much of this article is based on that treatment.

For a complete survey of all of Barwise's papers on situation theory and situation semantics, see the 2004 article Devlin [8].

For an extended discussion of the application of situation semantics to the resolution of the classical Liar Paradox, see Barwise and Etchemendy's 1987 book [2].

An excellent compilation of many of Barwise's papers on situation theory and situation semantics is provided by his 1989 monograph [1].

The 1997 book [5] by Barwise and Seligman provides an exploration of the situation theoretic notion of a constraint in a very general setting.

For an application of situation theory to decision making using an action- oriented approach, see Devlin and Rosenberg's 1996 monograph [9]. A less technical coverage of roughly the same material, aimed at the business world, is provided by Devlin's 1999 book [7].

See also the series of conference volumes *Situation Theory and Its Applications*, Volumes I, II, and III, all published in the CSLI Lecture Notes series (1991, 1992, 1993).

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