Anaphoric Reference to Events and Actions: A Representation and its Advantages

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Abstract

This paper focuses on anaphora interpreted as referring to entities of type event and action. It considers two issues: (i) what aspects of the discourse give evidence of the events and the actions the speaker is talking about, and (ii) how actions and events are represented in the discourse in order to be able to refer to them anaphorically.

1 Introduction

When people speak or write, they refer to things, objects, events, actions, facts or states that they (or other people) referred to before. They use certain words to "refer" or "point" to those things previously mentioned. Such context-dependent reference is called, **anaphora**, and the words used to "refer" are called **anaphors**. Some examples of anaphors include pronouns such as *he*, *she*, *it* and noun phrases that contain *this*, *that*, *these* and *those*. Consider for example the following pair of sentences:

(1) U: I want to move a block of text as a unit. How do I do *it*?

The *it* in the second sentence is the anaphor which points back to the action that the user wants to perform, described in the first sentence.

In our communications, we benefit from the use of anaphoric forms which make our interactions more coherent and intelligible. If we were forced to describe everything explicitly, our discourse would become very complex, long and time-consuming. Moreover it could become confusing and lead to potential misunderstandings. Such is the case in the following example which is similar to example (1) but in which a pronoun is not used in the second sentence:

(2) U: I want to move a block of text as a unit. How do I *move a block of text as a unit*?

We as listeners may find these sentences very odd and lacking coherence. We may wonder about the need to repeat the description which has already been introduced. If the speaker fails to use the pronoun, the listener may believe that he is meant to conclude something special from this unnatural usage. This conclusion may be unwarranted.

The work we present here describes the process of dealing with anaphoric language when the reference is to events and actions. It considers two issues: (i) what aspects of the discourse give evidence of the events and the actions the speaker is talking about, and (ii) how actions and events are represented in the discourse in order to be able to refer to them anaphorically. The overall goal is to make natural-language communication between human beings and machines more robust and coherent. This can be done by providing computer systems with the ability to adequately generate and interpret text which includes anaphoric references to events and actions in a similar way to how human beings do it. To illustrate the problem that we are dealing with, we use some examples taken from a set of natural language transcripts about the EMACS text editor. The users were given a task to perform using EMACS and at the same time they were able to ask an expert about the various things they could do in EMACS. The goal of the interaction was for the users to learn how to use the EMACS editting system.

In the next section we will describe how we view discourse models along with the representation of entities which form part of them. In section 3 we describe a representation of those entities based on the language used. We propose a generalization of that representation which allows us to have access to the different entities characterized by the text. In section 4 we relate the proposed representation with the particular pronouns used to refer to events, based on some data analysis. We conclude by giving a brief summary of what the advantages of the proposed representation are.

2 Discourse Models

An overall concern of this work is to describe how communication is done via **discourse**. A piece of discourse is a set of sentences or pieces of text that are spoken by one or more speakers. When we talk about discourse, we usually indicate the fact that those sentences in the discourse are connected in some way that makes them comprehensible and coherent. Speakers do so by attempting to get their listeners to construct an appropriate model: a **discourse model**. A discourse model is viewed as containing representations of entities, along with their properties and relations they participate in [Webber 1982, Heim 1982, Kamp 1984]. The key, then, in successful communication is for the speaker to transmit as much information about those representations of the entities, their properties and relations to the listener. Usually, this cannot be done in a single utterance, so it requires **reference** back to things mentioned previously. The speaker refers to a particular representation of a person, object, action or event in his or her discourse model and he or she can do so by using a pronoun, a definite noun phrase, or a form such as do *it*, do *that*. The speaker expects the listener to (i) have in his or her discourse model a representation for those objects, actions or events (or to be able to create one with minimal effort), and (ii) make the link between the referent[1] and the representation of the entity.

Discourse entities can represent objects, sets, actions, events, and facts which are viewed as individuals. The referent of a definite pronoun is then an entity in the speaker's discourse model which, given the goal of the communication, is expected to exist

[1] Research in linguistics has defined the problem of anaphora as that of finding the antecedent of an anaphoric expression, that is, finding the word or phrase to which the anaphor is linked. In this work, the problem of anaphora is defined not solely as that of identifying the antedecent but how the referent is found. We consider the *antecedent* to be the linguistic text which gives rise to an entity, as compared to a *referent* which is a non-linguistic entity.

also in the listener's model. In the next section, we describe how discourse entities describing events or actions can be represented in a discourse model in order to indicate what they make available for future reference.

3 Formalizing the Representation

3.1 Characterization

First, let us consider what characterizes actions or events. In general, each sentence gives rise to an **event**. Similarly, an **action** is considered to be part of that event. As a way to establish the differences linguistically, we describe **actions** as being characterized by the predicate of the sentence (the verb phrase) and **events** as being characterized by the whole sentence. Therefore, we consider actions to be part of events. This notion is similar to Jackendoff's who notes that "sentences that express [ACTIONS] are a subset of those that express [EVENTS]" [Jackendoff 1983] (p. 179). He proposes introducing "what happened was" as a diagnostic for [EVENTS] and "what x did" as a diagnostic for [ACTIONS]. So we have

(3) What happened was that the pig ran away. → EVENT

and

(4) What Fred did was run away. → ACTION

Within this view, "an [EVENT] that is also an [ACTION] involves a character with a special role– the one who is performing the [ACTION]," called the [ACTOR] (p. 180).

Consider for example:

(5) Mary deleted the region.

Here, the action of deleting, which occurred in some past time, was performed by Mary and it was done on the region.[2] The 'delete' action relates Mary and the region.

Events correspond to the conjunction of the action predicate with other predicates described in the sentence such as time, place, along with the agent performing the action. Tense and aspect usually indicate the sense of time in an event. The tense indicates present, past, or future and the aspect indicates the perfect (completion) and progressive (continuous) forms. In general, they are indicated syntactically by certain verbs and/or the auxiliaries. For instance, the auxiliary verb gives us a sense of whether the event is occurring (present), occurred (past), will occur (future)–or is just hypothesized–as well as whether an event is continuous or it has been completed.[3] Events and actions usually have associated with them a time interval. This time interval can have a well defined beginning and/or end. There may also exist events which occur as points, that is, their beginning and end times are the same as well as those in which there is no end or no beginning. These are among the issues that provide us with information about the event or the action. There is a vast literature of these subjects including works by [Vendler 1967, Mourelatos 1978, Dowty 1986, Hinrichs 1986, Moens et al. 1987, Passonneau 1987] to mention some.

[2]In EMACS, a region is a block of text defined by the mark at one end and the cursor at the other end. More precisely, it is the area of the buffer between the dot and the mark.

[3]English has two divisions for aspect: (i) Progressive (verb *to be* and the verbal form *-ing*) and non-Progressive, and (ii) Perfect (verb *to have* and Past Participle) and non-Perfect. English also has a separate Habitual (which occurs only in the past tense), using the auxiliary form *used to*. The habitual can be replaced by its non-habitual equivalent, i.e. the non-habitual does not exclude habitual meaning [Comrie 1976].

To summarize, our characterization of events is based on individual sentences. Each event includes an action predicate which, along with other predicates describing tense, aspect, and the agent performing the action constitutes the particular event.

3.2 Representation of Events

Given our characterization of events and actions as described before, and assuming a syntactic representation for each sentence, the next step is to describe the kind of (semantic) representation we use to characterize those events. Many representations for events have been proposed to handle similar issues as we describe here [Davidson 1967, Moore 1981, Neale 1987]. The representation we have chosen is λProlog, a formal logical representation described by [Miller et al. 1986]. This approach allows us to represent entities describing events and actions in a logical and complex way. In this representation, the logical form describes the events that characterize the sentence (as compared to a proposition or individual), therefore allowing subsequent references to any one of the events described by the sentence. For example,

(6) Mary types control-W.

which is usually represented as

$$type(Mary, control\text{-}W),$$

will get mapped onto the following semantic representation:

$$\exists v[type(Mary, control\text{-}W, v)],$$

which posits an individual typing event following [Davidson 1967]. From this semantic representation, we obtain the action described by the sentence which corresponds to its **predicate** (e.g. 'type control-W' in this example). This action can be represented in terms of λ predicates as in,

$$\lambda x.[type(x, control\text{-}W, e)].$$

The sentence characterizes an event description which is represented as

$$\mathbf{E} : \lambda e.[type(Mary, control\text{-}W, e) \wedge present(e)],$$

meaning that **E** is an entity describable as 'the event in which Mary types control-W'. This is the entity associated with the event description characterized by the sentence. *Present(e)* means that the event occurs now.[4] As a way of illustrating the representation, consider an example:

(7) John was shot in broad daylight in Philadelphia.

which can be represented as follows:

$$\mathbf{E}_{(7)\text{-}1} : \lambda e.[\exists x[shoot(x, John, e)] \wedge during(daylight\_hours, e) \wedge in(Philadelphia, e) \wedge past(e)].$$

[4][Hobbs 1985] describes a similar approach by introducing what he calls a "nominalization" operator $' : p \mapsto p'$:

> Corresponding to every n-ary predicate p there will be an $(n+1)$-ary predicate p' whose first argument can be thought of as the condition that holds when p is true of the subsequent arguments. Thus if *run(J)* means that John runs, *run'(E,J)* means that E is a running event by John, or John's running. .....The effect of this notational maneuver is to provide handles by which various predications can be grasped by higher predications (p. 62).

Here, $\mathbf{E}_{(7)\text{-}1}$ can be described as 'the event in which John was shot in broad daylight in Philadelphia'.[5] $\mathbf{E}_{(7)\text{-}1}$ corresponds to the real world event description in which John was shot which took place at a time during the daylight_hours, in Philadelphia. x is the person who did the shooting, who is not explicitly mentioned in the sentence. Here, *past(e)* is defined as

$$past(e) \Rightarrow time(e) < now.$$

So $\mathbf{E}_{(7)\text{-}1}$ makes a predication about the event in which John was shot and the details that form part of that predication.

Given this representation of the event, the next issue is how to generate references to that event. That is, we want to be able to generate references to (7) as in:

(8) John was shot in broad daylight in Philadelphia. *It* happened at 10 am.
it = the event in which John was shot in broad daylight in Philadelphia.

(9) John was shot in broad daylight in Philadelphia. *It* shocked me very much.
it = the event in which John was shot in broad daylight in Philadelphia.

(10) John was shot in broad daylight in Philadelphia. *It* has never happened before.
it = an event in which someone was shot in broad daylight in Philadelphia.

(11) John was shot in broad daylight in Philadelphia. Al Pacino had done *it* last year in a warm summer evening in New York City.
it = shoot someone/John.

(12) John was shot in broad daylight in Philadelphia. *That* would never happen in Bogotá.
that = an event in which someone was shot in broad daylight.

As seen in these examples, the referents of the pronouns may have been introduced explicitly. That is, the anaphoric expression in the second sentence can refer to the specific event as characterized by the sentence or to a less specific event than the one described by the sentence. Therefore, what we need is to have access to the specific event description along with more general event descriptions of the one characterized by the sentence. This representation allows us to do so by being able to perform a generalization on the specific event description as we show in the next section.

3.3 Generalization of Event Descriptions

In general, each event represented as described in the previous section denotes a set of events. Given that there are entities corresponding to events represented in the discourse model, each of which can have one or more descriptions, we can **generalize** to obtain the various descriptions. **Generalization** is defined as follows: Given an event description $\mathbf{E}_1$ and an event description $\mathbf{E}_2$, we say that $\mathbf{E}_1$ **generalizes** $\mathbf{E}_2$ if every event description denoted by $\mathbf{E}_2$ is a member of the set of event descriptions denoted by $\mathbf{E}_1$.[6]

As we generalize the representation of the event that we have obtained for each sentence, we incrementally obtain event descriptions of that event. These event descriptions are available in the discourse model for future reference. The generalization of the events fits in an ordered structure in which the most specific representation (corresponding to the description of the event characterized by the original sentence) is at the bottom and the most general at the top. So if we consider (7) again

(7) John was shot in broad daylight in Philadelphia.

along with its representation

$$\mathbf{E}_{(7)\text{-}1} : \lambda e.[\exists x[shoot(x, John, e)] \wedge during(daylight\_hours, e) \wedge in(Philadelphia, e) \wedge past(e)].$$

We can generalize it to 'any person y' (being shot) as follows:

$$\mathbf{E}_{(7)\text{-}2} : \lambda e.[\exists x \exists y[shoot(x, y, e)] \wedge during(daylight\_hours, e) \wedge in(Philadelphia, e) \wedge past(e)].$$

We can further generalize to 'any place p' and obtain:

$$\mathbf{E}_{(7)\text{-}3} : \lambda e.[\exists x \exists y[shoot(x, y, e)] \wedge during(daylight\_hours, e) \wedge \exists p[in(p, e)] \wedge past(e)].$$

And we can continue to generalize this last representation and obtain the following:

$$\mathbf{E}_{(7)\text{-}4} : \lambda e.[\exists x \exists y[shoot(x, y, e)] \wedge during(daylight\_hours, e) \wedge past(e)].$$

$$\mathbf{E}_{(7)\text{-}5} : \lambda e.[\exists x \exists y[shoot(x, y, e)] \wedge \exists p[in(p, e)] \wedge past(e)].$$

$$\mathbf{E}_{(7)\text{-}6} : \lambda e.[\exists x \exists y[shoot(x, y, e)] \wedge past(e)].$$

$$\mathbf{E}_{(7)\text{-}7} : \lambda e.[\exists x \exists y[shoot(x, y, e)]].$$

As specified by the generalization, every member of $\mathbf{E}_{(7)\text{-}1}$ is a member of $\mathbf{E}_{(7)\text{-}7}$. This set of generalizations can be ordered in a graph-like structure as shown in Fig. 1.

In this structure, which provides a partial ordering of the events, some events are more specific than others. The structure is partially ordered, with the $\leq$ relation.[7] We have not generalized to 'any time t' in the 'during' predicate because all events occur during some time. Note that at the very bottom of our graph we could generalize on the predicate 'shoot' so as to have an event describing "somebody doing something" which is common to all events. We have chosen not to do so in order to have access to the initial referent of the pronoun, characterized by the predicate of the event.

The generalization structure provides the potential referents for the pronouns as they appear in examples (8), (9), (10), (12), and (11). Consider for instance, the pair of sentences in (10), where the referent of the pronoun *it* in the second sentence is "an event in

[5] As pointed out by [Sidner 1982], referring expressions *specify* discourse entities; referring expressions may *co-specify* the same discourse entity; discourse entities *represent* objects or events in the world and people *refer* to objects and events in the world when they use referring expressions.

[6] This definition is based on Miller and Nadathur's definition of *subsumption* (= generalization). They define it in terms of *concepts* as follows: "a concept C_1 subsumes another concept C_2 if every element of the set denoted by C_2 is a member of the set denoted by C_1" [Miller et al. 1986] (p. 6).

[7] A relation $\preceq$ is called a *partial order* if it is *reflexive* ($p \preceq p$), *anti-symmetric* ($p \preceq q \wedge q \preceq p \Rightarrow p = q$), and *transitive* ($p \preceq q \wedge q \preceq r \Rightarrow p \preceq r$).

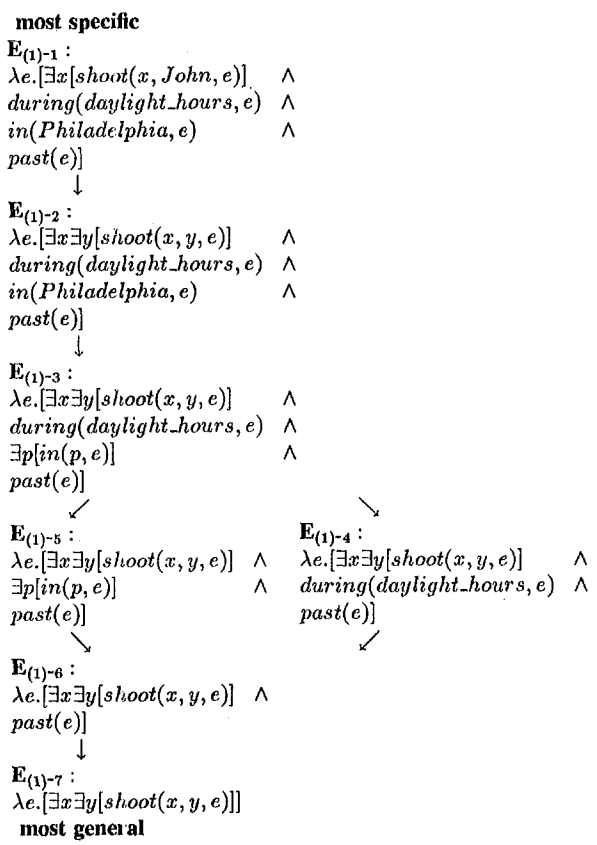

Figure 1: Generalization of 'John was shot in broad daylight in Philadelphia'

which someone was shot in broad daylight in Philadelphia?. This event description is $\mathbf{E}_{(7)\text{-}4}$ which is available in the generalization graph. The same is true for the pair of sentences in (11) where the referent of the pronoun *it* is $\mathbf{E}_{(7)\text{-}7}$, and the pair (12) where the referent of the pronoun *that* in the second sentence is $\mathbf{E}_{(7)\text{-}5}$, both of which are available thru the generalization graph.

Bauerle has proposed an alternative method for dealing with event reference within the framework of Discourse Representation Theory (DRT) [Kamp 1984]. As he points out, the problem is not that simple because by introducing an event-argument, the possible referents for event-anaphora are only linked to the event-token (the specific event description) and not to the type (the generalized descriptions) [Bauerle 1988] (p. 21). The representation outlined in this paper does provide us with access to the event-token and its generalization allows us to obtain the types.

4 Relationship between Pronouns and their Referents

In addition to relating a particular pronoun and its referent, either as a specific event-token or as an event-type obtained from the generalization of the event-token, there are cases in which the pronoun is also linked to not just an individual event but to either a sequence of events or even a particular event within a sequence (usually the last event in the sequence).

As described in [Schuster 1988], we have studied the relationship between the pronouns and their referents, within a given text describing a sequence of events. We focused on the use and interpretation of the pronouns *it* and *that* when referring those events and/or actions, given the representation described in the previous section. Initially, we were interested in identifying the relationship between a specific pronoun such as *that* or *it* and an event as its referent. We found out that a particular pronoun could act as a referent of one of the following:

1. One event.
2. A sequence of events, the pronoun referring to the entire sequence as one.
3. The last event in a sequence.
4. A pair of events related by two possible relations: **generation** and **enablement**, as proposed by [Goldman 1970] and developed by [Pollack 1986a].

We will describe each one of these cases, along with some examples and relate them to the representation we introduced in section 3.

1. One event Consider the following text:

(13) E: Write a simple macro that does three forward characters. Try *that*.

We can represent the first sentence in the pair as described before:

$$\mathbf{E}_{(13)\text{-}1} : \lambda e.[[write(U, 3fc\_macro, e)] \wedge present(e)].$$

Here, $\mathbf{E}_{(13)\text{-}1}$ can be described as 'the event in which U writes a simple macro that does three forward-characters, and takes place at the present time'. U in this case is the user interacting with the expert. Then, the referent of the pronoun *that* in the second sentence is the event represented as $\mathbf{E}_{(13)\text{-}1}$.

2. **A sequence of events** Consider:

   (14) E: To kill a region, the whole thing at one time you should set the mark– ⟨esc⟩-M–at the top of the region, then move the cursor down to the bottom of the region and type ⟨esc⟩control-K. *This* will kill the region.

   The pronoun *this* refers to the entire sequence of events. As in the previous case, if we represent each sentence as a λexpression, we have access to the various descriptions of the event corresponding to each sentence and we can refer to them via the pronoun.

3. **Last event** Consider the following example, where the pronoun *it* refers to the last event in the sequence:

   (15) E: To kill a word, you have to move the cursor to the beginning of that word and type control-D. Go ahead, do *it*.

4. **Generation and Enablement** In analyzing the data we found the need for two important relationships: **generation** and **enablement** [Pollack 1986b]. Generation is defined as follows: If an agent performs one action and thereby, without any effort on his/her part, does another, then we can say that his/her performance of the former action "generated" the performance of the latter. For example,

   (16) E: Do *this*: set a "mark" at some point (any old point) by typing ⟨esc⟩-M. It will say "mark set", try *it*.

   (17) E: ⟨esc⟩-M will give set-mark. Do *it*.

   In both cases, the referent(s) of the pronoun *it* can be either "setting the mark" or "typing ⟨esc⟩-M" or even both: "setting the mark by typing ⟨esc⟩-M". By viewing the referent in terms of the generation relationship, we can claim that "*U* typing ⟨esc⟩-M at a given time **generates** *U* setting the mark at that given time". This relationship allows us to refer to both or either of the referents without having to make a distinction between the two of them. Note that generation is a relationship between the specific events, the event-tokens and not the types.

   Enablement, as opposed to generation, has been described as follows: if an agent performs an action and thereby puts the world in a state in which a second action will generate a third action, then we can say that the agent's performance of the first action **enables** the generation of the third by the second. For example,

   (18) U: I want to move the cursor 20 characters to the right. How can I do *it*?
   E: Like all other commands in EMACS, these commands can be given arguments which cause them to be executed repeatedly. The way you give a command a repeat count is by typing control-U and then the digits before you type the command. For instance, control-U 20 ⟨RIGHT-ARROW⟩ moves forward 20 characters. Go ahead, try *that*.

   In this example, the pronoun *that* refers to the entire enablement relationship: "*U* typing control-U **enables** a given number (20) and the RIGHT-ARROW key to be typed which in term generates the cursor to move 20 characters forward". *U* typing control-U is viewed as an enablement relationship: if *U* does not type control-U and only types 20 followed by the RIGHT-ARROW, *U*'s desired goal of making the cursor move 20 characters forward will not be accomplished.

To summarize, for each representation of the individual events characterized by each sentence, we can relate the pronoun to the event, to a sequence of events, or to events related by either the generation or enablement relationships.

5 Summary

We have defined an approach for representing actions and events in discourse in order to refer to them anaphorically. The main concern has been to describe what aspects of the discourse give evidence of events and actions and how these events and actions are represented in order to refer to them appropriately. This representation has the advantage that it allows us to create appropriate descriptions of actions and events which are available for future reference in the discourse model. We have shown how to generalize event descriptions, so that the general event descriptions can in turn be associated with additional event entities required by the use of particular anaphoric expressions. We have also related the event representation described here to anaphoric pronouns, given that the pronouns can refer to more than one event.

Acknowledgments

This work was supported by ARO grant DAAG29-84-K-0061, DARPA grant N00014-85-K-0018, and NSF-CER grant MCS82-19196 to the University of Pennsylvania. My thanks to Bonnie Webber and Dale Miller for their coments on an earlier draft. I am specially grateful to Haim Levkowitz for his comments, and for his immense help in formatting this paper.

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