An Approach to the Representation of Iterative Situations

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Abstract

Iterative sentences such as *Mary knocked on the door four times*, *John played the sonata every other day*, and *Mary was often busy* can be understood as asserting that some situation type is either repeated a certain number of times or with a certain frequency. The semantic content of iterative sentences has been standardly represented by some logical formula which quantifies over instances of a non-iterative situation type. The principal claim of this paper, and the basis of the representations proposed in it, is that we also require iterative situation types and instances in order to completely handle the range of possible interpretations of iterative sentences.

Introduction

Iterative sentences such as *Mary knocked on the door four times*, *John played the sonata every other day*, and *Mary was often busy* can be understood as asserting that some situation type is either repeated a certain number of times or with a certain frequency. As with so many topics in the analysis of temporal information in natural language, one of the earliest discussions of the semantics of iterative sentences is in (Bennett & Partee 1972). Important discussions are also given in (Aqvist, Hoepelman, & Rohrer 1980), (van Eynde 1987), and (Parsons 1990). In all of these treatments, the semantic content of iterative sentences is essentially represented by some logical formula which quantifies over instances of a **non-iterative situation type**. The principal claim of this paper, and the basis of the representations proposed in it, is that we also require **iterative situation types** and instances in order to completely handle the range of possible interpretations of iterative sentences.

The first section of this paper presents an overview of the basic, i.e., non-iterative, situation types which function as the fundamental components of the iterative types. The second section briefly discusses the representation of the aspectual progressive. It will be shown that the range of possible interactions between the progressive and iterative modifiers provides important clues to the structure of the iterative types. In the following section, the different kinds of iterative situations are described, and approaches to the representation of two of the principal types—**cardinality iteratives** and **definite period frequency iteratives**—are proposed. In the final section, these approaches are extended to include iteratives of iteratives.

The Basic Aspectual Classes

What are commonly called the *aspectual classes* are sets of event or situation types grouped together primarily on the basis of their temporal properties. This section presents a brief overview and systematization of the basic, i.e., non-iterative, aspectual classes which will provide a foundation for the discussion of iteratives that follows. The most familiar of these aspectual classes—achievements, accomplishments, activities, and states—come from the work of (Vendler 1967), and have been intensively studied for many years. Since Vendler's original discussion, it has become clear that many of the components of a sentence can affect the ultimate classification of the situation described or expressed by that sentence. Excellent discussions of this notion of "aspectual composition" can be found in (Dowty 1979) and (Verkuyl 1972, 1989).

In (Almeida 1989, 1991), the aspectual classes are analyzed according to three fundamental and roughly orthogonal distinctions. The first of these distinctions is that situation types in general can be divided into three major classes depending on the nature of the intervals of time at which they can hold or occur: **point-situations**, which can only hold/occur at instantaneous points of time, **interval-situations**, which can only hold/occur at noninstantaneous intervals of time, and **point-interval-situations**, which can hold/occur at both instantaneous and noninstantaneous periods of time.

The second distinction is between situations which are **homogeneous** in overall structure, so that the parts are of the same nature as the whole, and those which are **heterogeneous**, that is, consisting of distinct stages, phases, or sub-situations. The most significant difference between homogeneous and heterogeneous situations is that homogeneous situations have the so-called *subinterval* property, while heterogeneous situations do not. A situation type has the subinterval property if all of the subsituations (down to a certain "grain size") of any instance of that situation type are themselves instances of that same type. In addition, homogeneous situations take for-adverbials to indicate their duration, while heterogeneous situations take in-adverbials. The third distinction is the contrast between **dynamic situations,** which involve change of some sort, and **nondynamic (stative) situations,** which do not.

Using these three criteria, Vendler's original classes can be characterized as follows: **achievements,** such as those expressed by *Mary fell asleep* and *John reached the top*, are heterogeneous dynamic point-situations; **accomplishments**, such as those expressed by *Mary played the sonata* and *John ran a mile*, are heterogeneous dynamic interval-situations; **activities**, such as those expressed by *John ran* and *Mary played the piano*, are homogeneous dynamic interval-situations; and **states**, such as those expressed by *Mary is busy* and *John is tired*, are homogeneous nondynamic point-interval-situations.

The Aspectual Progressive

The progressive construction in English, i.e., the combination of auxiliary *be* and the *-ing* form of the main verb, has an unusually wide range of uses. Probably the most important use of the progressive is the **aspectual progressive**. It is the aspectual progressive which is being contrasted with the simple, i.e., nonprogressive, construction in such pairs of sentences as *John was running at three o'clock* versus *John ran at three o'clock*, and *Mary was speaking when I entered the room* versus *Mary spoke when I entered the room.*

In the theory of the aspectual progressive described in (Almeida 1989, 1991), progressive situations are represented using a function, **prog**, which is defined as taking as its single argument a homogeneous interval-situation type, and as having as its value the corresponding homogeneous point-interval-situation type—a progressive situation type. Since **prog** can only be applied to homogeneous interval-situations, the formation of the progressives of heterogeneous situations requires the use of an additional function, **hm**, which takes as its argument a heterogeneous interval-situation type, and has as its value the corresponding homogeneous interval-situation type. Thus, **hm** can be understood as a "homogenizing" function which, among other things, has the effect of changing the temporal properties of the situation types it is applied to. Similar ideas to this conversion of a heterogeneous situation to a homogeneous situation, generally as a step in the formation of progressive situations, occur in the theories of (Bennett 1981) and (Moens & Steedman 1988).

As examples of the application of these functions, consider the sentences *John played the piano* (an activity) and *John played the sonata* (an accomplishment). For the purposes of this paper, their semantic content can be represented as follows:

(1) $\exists$(e,t)[inst(e,play(john1,piano1)) & time(e,t)]
(2) $\exists$(e,t)[inst(e,play(john1,sonata1)) & time(e,t)]

In these formulas *e* represents an instance of the relevant situation type, and this instance is asserted to hold/occur at time *t*. (note: throughout this paper tense will be disregarded.) The corresponding progressive sentences have the representations:

(1) $\exists$(e,t)[inst(e,prog(play(john1,piano1))) & time(e,t)]
(2) $\exists$(e,t)[inst(e,prog(hm(play(john1,sonata1))))
& time(e,t)]

Iterative Situations

Iterative situations can be understood as being composed of some underlying component situation type which is either repeated a certain number of times or with a certain frequency. We can, therefore, distinguish two major types of iterative situation: (1) **cardinality iteratives**—where the component situation type is conceived of as being repeated some number of times, and (2) **frequency iteratives**—where the component situation type is conceived of as being repeated with a certain frequency. The temporal properties, and hence the representations, of these two classes differ significantly.

Cardinality Iteratives

Cardinality iterative situations are expressed through the use of adverbials of number or cardinality, such as *five times*, *several times*, and *twice*. For example, *John played the sonata twice* describes an iterative situation consisting of two component situations, each of the type **play(john1,sonata1)**. All cardinality iterative situations are heterogeneous interval-situations, regardless of the nature of their component situations, so their durations are given by in-adverbials, as in, for example, *John was sick twice in a week.*

Parsons (1990) contends that cardinality adverbials can quantify over either times or events. For example, *Twice, Brutus stabbed Caesar* seems to say there are two separate times or occasions at which Brutus stabbed Caesar. On the other hand, *Brutus stabbed Caesar twice* allows the continuation: *But both stabbings were simultaneous; one was in the back and one in the thigh* (p.224). Parsons' representation for *Brutus stabbed Caesar twice* is (p.311, note 11):

$(\exists$ I)[I < now
& $(\exists e_1)(\exists e_2)[e_1 \neq e_2$
& $(\exists$ t)[member(t,I)
& stabbing(e_1) & agent(e_1,Brutus)

$\quad\quad$ & theme(e_1,Caesar) & cul(e_1,t)]
& ($\exists$ t)[member(t,I)
$\quad\quad$ & stabbing(e_2) & agent(e_2,Brutus)
$\quad\quad$ & theme(e_2,Caesar) & cul(e_2,t)]]]

In this formula, the predicate **cul** asserts that the event represented by its first argument culminates or comes to a successful conclusion at the point of time represented by the second argument. (It should be noted that the particular method used to represent the basic situation types is not significant to the points I wish to make in this discussion.) Parsons' representation for *Twice, Brutus stabbed Caesar* is (p.311, note 10):

($\exists$ t_1)($\exists$ t_2)[$t_1 \neq t_2$
& ($\exists$ I)[I < now & at(I,t_1)
$\quad$ & ($\exists$ e)($\exists$ t)[member(t,I)
$\quad\quad$ & stabbing(e) & agent(e,Brutus)
$\quad\quad$ & theme(e,Caesar) & cul(e,t)]
& ($\exists$ I)[I < now & at(I,t_2)
$\quad$ & ($\exists$ e)($\exists$ t)[member(t,I)
$\quad\quad$ & stabbing(e) & agent(e,Brutus)
$\quad\quad$ & theme(e,Caesar) & cul(e,t)]]]

While the distinction between iteratives in which the component events may be simultaneous and those in which the component events must be non-simultaneous is an interesting one, I am inclined to treat it as a difference in the implicatures of these sentences rather than as reflecting a fundamental difference in logical form. Since Parsons' event iteration is ambiguous with respect to these two possibilities, it seems to be the more basic of these representations. Also, it will be shown below that the difference between sentence-initial and sentence-final modifiers can be understood instead as reflecting a difference in the scope possibilities of the modifier in logical form.

Parsons' representations of cardinality iteratives have two significant shortcomings. The first is the awkward way in which the cardinality information is represented—in both cases it is necessary to explicitly incorporate as many tokens of times or events as is given by the cardinality adverbial. This is easy enough to do when the cardinality is two or three, but this approach becomes impractical as the number of times/events increases.

However, a more fundamental problem with these representations is the absence of any tokens to represent the iterative situations or the iterative types themselves. Why might we need such tokens? One possible reason is to serve, as in the case of non-iterative events, as the objects of perception predicates such as **see** or **hear**. For example, in the sentence *Cassius saw Brutus twice stab Caesar,* it could be argued that what Cassius saw was an iterative event consisting of two instances of Brutus stabbing Caesar. But, it could also be argued that Cassius did not see an iterative event at all but only its component events, the individual stabbings. It will be shown that a stronger argument for the need for tokens for iterative situations and types is the existence of progressive iterative sentences such as *Brutus was stabbing Caesar twice* and *John was playing the sonata three times.*

The proposed representation for the cardinality iterative situation expressed by the sentence *John played the sonata twice,* an iterated heterogeneous situation, is:

$\exists$(e,t)[inst(e,play-twice) & time(e,t)]

subtype(play-twice,cardinality-iterative-type)
& cardinality-of(component-set-of(play-twice)) = 2
& time(play-twice,time-of(play-twice))
& $\forall$(e)[member(e,component-set-of(play-twice))
$\quad\quad$ $\rightarrow$ $\exists$(t)[inst(e,play(john1,sonata1)) & time(e,t)
$\quad\quad\quad$ & during(t,time-of(play-twice))]]

In these formulas, the token **play-twice** represents the iterative situation type, which is conceived of as a set of events where the cardinality of the set is given by the cardinality adverbial. The representation for the sentence *Twice, John played the sonata* is essentially the same, except that there may be an additional assertion to the effect that the component events cannot be simultaneous. Actually, the nature of many situation types precludes the possibility of simultaneity regardless of the sentence position of the iterative adverbial.

The difference in scope possibilities between sentence-initial and sentence-final modifiers becomes manifest in progressive iterative sentences. For example, the sentence *John was playing the sonata twice* is ambiguous between the following two readings:

(1) $\exists$(e,t)[inst(e,prog(hm(play-twice))) & time(e,t)]
(2) $\exists$(e,t)[inst(e,playing-twice) & time(e,t)]

subtype(playing-twice,cardinality-iterative-type)
& cardinality-of(component-set-of(playing-twice)) = 2
& time(playing-twice,time-of(playing-twice))
& $\forall$(e)[member(e,component-set-of(playing-twice))
$\quad\quad$ $\rightarrow$ $\exists$(t)[inst(e,prog(hm(play(john1,sonata1))))
$\quad\quad\quad$ & time(e,t)
$\quad\quad\quad$ & during(t,time-of(playing-twice))]]

The first reading is the progressive of the iterative situation itself, as in *(At 5 o'clock), John was (in the process of) playing the sonata twice.* In contrast, the second reading is that there were two occurrences of John's being in the process of playing the sonata. This is also the interpretation of *Twice, John was playing the sonata.* In the first reading, the progressive function has a wider scope than the cardinality iterative modifier, while in the second reading the iterative modifier has the wider scope. Parsons is able to represent the second reading but not the first.

John played the piano twice, an iterated activity situation, has an analogous representation, and its progressive similarly has two possible interpretations. When the component event type is homogeneous, as in this example, the instances of the component type must always be temporally separate from one another, that is, there must be a temporal gap of some sort between each pair of instances of the component type.

In summary, the general pattern for the proposed representation of cardinality iteratives is as follows (note: capitalized symbols would be replaced by the relevant values):

∃(e,t)[inst(e,Card-Iter-Type) & time(e,t)]

subtype(Card-Iter-Type,cardinality-iterative-type)
& cardinality-of(component-set-of(Card-Iter-Type))
    = Number
& time(Card-Iter-Type,time-of(Card-Iter-Type))
& ∀(e)[member(e,component-set-of(Card-Iter-Type))
    → ∃(t)[inst(e,Component-Type) & time(e,t)
        & during(t,time-of(Card-Iter-Type))]]

Frequency Iteratives

Frequency iterative situations are expressed through the use of adverbials of frequency, such as *often, always, occasionally, every hour*, and *every other day*. (Quirk et al. 1972) distinguish two major subclasses of frequency adverbials: **definite period frequency adverbials** and **indefinite frequency adverbials**. The definite period frequency adverbials (called periodic cyclic adverbials in (van Eynde 1987)), e.g., *every hour, weekly, every other day,* explicitly name the times by which the frequency is measured, while the indefinite frequency adverbials (called proportion adverbials in (Parsons 1990) and indefinite cyclic adverbials in (van Eynde 1987)), e.g., *often, always, usually, occasionally*, do not.

All frequency iteratives are homogeneous situations. This seems intuitively right, and is confirmed by the fact that all frequency iteratives can take for-adverbials, as in, for example, *John played the sonata every other day for a month.* Of course, they may have a very large "grain size", hence the oddness of *For five minutes, John played the sonata every other day.* In addition, frequency iteratives can be either interval-situations or point-interval-situations, depending on the nature of the component situation type.

Indefinite frequency adverbials are often used in statements of habituality, as well as in nontemporal sentences such as *A quadratic equation usually has two roots* (Lewis, 1975). These adverbials are also discussed in (Bennett & Partee 1972), (Aqvist, Hoepelman, & Rohrer 1980), (van Eynde 1987), and (Parsons 1990). The representation of these iterative situations usually involves the use of generalized quantifiers. In this paper, only definite period frequency iteratives will be dealt with.

The proposed representation for the definite period frequency iterative *John played the sonata every day* is:

∃(e,t)[inst(e,play-every-day) & time(e,t)]

subtype(play-every-day,def-period-freq-iterative-type)
& time(play-every-day,time-of(play-every-day))
& ∀(t)[(member(t,sequence-of(days))
        & during(t,time-of(play-every-day)))
    → ∃(e′,t′)[inst(e′,play(john1,sonata1))
        & time(e′,t′) & during(t′,t)]]

It is necessary to make use of a sequence of days, rather than simply a set, because of the possibility of using quantifiers like *every-other* and *every-third* which presuppose an ordering. Van Eynde's (1987) representation for definite period frequency iteratives is similar to the one proposed here, except that it does not incorporate the notion of a sequence of intervals, and, most importantly, there is no token for the iterative situation itself.

As in the case of cardinality iteratives, the progressive function has scope interactions with the frequency iteration modifiers. For example, *John was playing the sonata every day* is ambiguous between two interpretations, which can be represented as follows:

(1) ∃(e,t)[inst(e,prog(play-every-day)) & time(e,t)]
(2) ∃(e,t)[inst(e,playing-every-day) & time(e,t)]

subtype(playing-every-day,def-period-freq-iterative-type)
& time(playing-every-day,time-of(playing-every-day))
& ∀(t)[(member(t,sequence-of(days))
        & during(t,time-of(playing-every-day)))
    → ∃(e′,t′)[inst(e′,prog(hm(play(john1,sonata1))))
        & time(e′,t′) & during(t′,t)]]

The first reading is the progressive of the frequency iterative type itself. The second reading is more clearly expressed by *Every day, (when Mary got home,) John was (in the process of) playing the sonata*, that is, the iteration of the progressive.

In the case of the cardinality iteratives, the instances of the component situation type must be properly individuated from one another. Is this also true in the case of frequency iteratives? When the underlying component situation type is heterogeneous, the issue does not arise, but what happens if it is homogeneous, as in *Mary played the piano every day* ? This sentence suggests that there were temporally-separated instances of piano playing, but is this necessarily so? In particular, if we know that Mary played the piano non-stop from 12:00 to 5:00, can we still truthfully say that *Mary played the piano every hour (from 12:00 to 5:00)*? I believe that we can. Therefore, with frequency iteratives, no assumptions can be made about the separateness of the "instances" of the underlying situation type. This is the reason that the component events of frequency iteratives are not represented as constituting a set, as they are in cardinality iteratives.

In summary, the general pattern for the proposed representation of definite period frequency iteratives is:

∃(e,t)[inst(e,Def-Freq-Type) & time(e,t)]

subtype(Def-Freq-Type,def-period-freq-iterative-type)
& time(Def-Freq-Type,time-of(Def-Freq-Type))
& Quantifier(t)[(member(t,sequence-of(Interval-Type))
& during(t,time-of(Def-Freq-Type)))
→ ∃(e′,t′)[inst(e′,Component-Type) & time(e′,t′)
& during(t′,time-of(Def-Freq-Type))]]

Iteratives Of Iteratives

Iterative situations can themselves be iterated quite freely, as in, for example, *John played the sonata twice every day, John played the sonata every other day (for a week) twice, John played the sonata three times (in a row) twice,* and *John played the sonata every other day (for a week) every month.* The representations for iteratives of iteratives are generated in a straightforward fashion—the representations as described above are simply embedded within one another depending on the scope relations of the iterative modifiers. For example, *John played the sonata twice every day,* where a cardinality iterative is within the scope of a definite frequency iterative, has the interpretation:

∃(e,t)[inst(e,play-twice-every-day) & time(e,t)]

subtype(play-twice-every-day,def-period-freq-iter-type)
& time(play-twice-every-day,
time-of(play-twice-every-day))
& ∀(t)[(member(t,sequence-of(days))
& during(t,time-of(play-twice-every-day)))
→ ∃(e′,t′)[inst(e′,play-twice) & time(e′,t′)
& during(t′,t)]]

As defined previously, **play-twice** is the type for *John play the sonata twice.* Representations for *Every day, John played the sonata twice* and *Twice every day, John played the sonata* can be similarly generated. Finally, the progressive *John was playing the sonata twice every day* has three possible interpretations, all of which can easily be represented using this approach.

Conclusion

In this paper, approaches to the representation of two major types of iterative situation—cardinality iteratives and definite period frequency iteratives—were proposed. In addition, some of the major temporal properties of these iterative types were described. Most importantly, I have argued that we require iterative situation types in our semantic representations.

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