Formal Description and Explanation

of Temporal Properties of Sentences

Machida, Ken

Abstract

The temporal properties of the events expressed by sentences are the results of the composition of the aktionsarts and the tense-aspect forms. Explanation of how the temporal properties are obtained requires the precise descriptions of the temporal factors in the events as well as the detailed clarification of the composing process of these factors. In order to properly achieve this purpose, formal expressions is one of the means linguistic studies can hopefully choose. This paper aims to present as sophisticated a formalization as possible so as to succeed in explaining the intuitional understanding of the temporal properties of the events denoted by sentences.

0. Introduction

A long tradition exists of studies, both general and particular, on the temporal structure and property of tense and aspect forms. Results of the researches are abundant treating the temporal and aspectual meanings sentences express in a large number of natural languages (Guillaume 1929, Reichenbach 1947, Clifford 1975, Binnick 1991, Kudo 1995 etc.). What is important in describing and explaining the temporal properties of sentences in any particular language with or without tense or aspect morphemes is the classification of verbs or predicates from the temporal point of view. Many of the previous studies on this subject take as their theoretical basis the verb classification by Vendler (1967) and Kindaichi (1947), the latter especially for studies on the Japanese langue.

The principal criteria of classification put forward in these studies are, first, whether the event denoted by the verb is a state or not, and second, when the event is not a state, whether the event is punctual or not. According to the criteria, the verbs are classified into state verbs, activity verbs and punctual verbs. As a more detailed characterization of activity verbs, Vendler presents a division into activity and accomplishment verbs, the former denoting non-state atelic events while the latter denoting non-state telic events. Though fairly easy to understand and widely used in quite a large number of influencial studies on the subject in question, these classifications of verbs are not satisfactory with regards their exactness and their power of explaining how temporal meanings of sentences are obtained in the process of understanding natural language sentences. For they give no clear definition of what a state is or what essentially constitutes the difference between telic and atelic events. In fact, both Kindaichi and Vendler define states verbs as the verbs expressing states. It goes without saying that such definitions as theirs are far from satisfactory because they are obvious examples of a sheer tautology.

Without a precise characterization of the verbs belonging to each type, it will hardly be ever possible to make a linguistically rational explanation of the temporal behaviors or meanings of sentences, say why sentences

with state verbs don't need morphemes expressing the progressive aspect, or say why sentences using non-state predicates with a non-past tense form usually can't refer to the present moment.

Another point to be considered is the habitual event and the eternal truth which sentences can sometimes express. Languages having morphemes for the habitual aspect naturally can express habitual events adding these morphemes to predicates. [1] But most of the languages lack such distinct habitual aspect markers. In spite of the lack of such specific markers, they do express habitual events having recourse to several intra-linguistic and extra-linguistic means like the semantic property of noun phrases and the additional function of existent tense forms. Thus a proper treatment of the temporal properties of sentences requires not only the well-defined verb classification but also the precisely clarified way of composing the meanings of nouns and predicates to produce the meanings of sentences in terms of temporal properties.

Taking into consideration the problems to be solved with regards the clarification of how the temporal properties of sentences are obtained through the process of composing morpheme meanings, I will try, in this paper, to define as precisely as possible the essential qualities of each verb class and to make a satisfactory explanation of the way the temporal properties of sentences are obtained.

1. Aktionsarts

Verb classes defined in terms of temporal properties of the events they denote have traditionally been called "aktionsarts". Since the aktionsarts are classes of events considered from the viewpoint that they take place on the timeline, what defines them should be the way the events they denote occupy the time interval on the timeline. Though the traditional aktionsarts like Vendler's classification (states, activities, accomplishments, achievements) seem to be intuitionally correct, they lack theoretical preciseness because they don't take into account the difference of quality among the time intervals given by the events each aktionsart represents.

In this respect, we give new definitions of aktionsarts, proposing new appropriate terms for each reconsidered conception of aktionsart as the following:

(1) **Aktionsarts**
Perfect homogeneity verb: be, have, love, resemble, differ, seem etc.
Partial homogeneity verb: run, walk, fly, turn, dance, speak, fight etc.
Heterogeneity verb: change, build, cook, push, paint, destroy etc.
Punctual verb: die, be born, arrive, leave, put, snap etc.

The essential criterion for classifying the above aktionsarts is, as the terms used for them show, whether the parts of the event designated by the verbs are qualitatively equal to the integral part (the whole) of the event. Differences are observed for the relations between the parts and the whole of the events for each aktionsart. For the precise definition of the aktionsarts, we introduce the term "momentary partial event" and "durative partial event". A momentary partial event is any part of an event occupying a point on the timeline, thus having no duration, though being properly recognized as a part of some event. A durative partial event is any part of an

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[1] Languages like Swahili, Lithuanian, Jamaican Creole etc. have morphemes to specify habitual events. cf. Hashimoto (1995), Nishimura(2004). Since the present tense form of English doesn't express events taking place at the moment of utterance, it has come to function as the habitual aspect marker.

event which occupies an interval of the timeline and which can properly be considered to be qualitatively equal to the whole event.

This way of classifying and defining partial events leads us to the qualification of the newly characterized aktionsarts as the following:

> (2) **characterization of aktionsarts**
>
> **Perfect homogeneity verb**: every momentary partial event is equal to the whole event
>
> **Partial homogeneity verb**: no momentary partial event is equal to the whole event, but every durative partial event, if adequately chosen, can be equal to the whole event
>
> **Heterogeneity verb**: neither momentary partial events nor durative partial events are qualitatively equal to the whole event
>
> **Punctual verb**: no partial event is included in the whole event

The essential property of the division of aspect into to types – perfective and imperfective, non-progressive and progressive etc. – is based on whether the event expressed by the sentence is a whole event or a partial event. Consider the following examples:

> (3) a. Tom was painting a picture.
>
> b. Tom painted a picture.

The event "paint [Tom, a picture]" [2] occupies a time interval necessarily longer than a moment, usually several hours or sometimes a few years. (3a) expresses the incompletion of the event in question, which means that the event had began at a time before the time interval it occupies and that it was expected to come to an end after the same time interval. Thus the time interval for the event denoted by (3a), with a so-called progressive aspect marker, occupies a part of the time interval for the whole event.

On the other hand, the event denoted by (3a) occupies the time interval required for the whole of the event "paint [Tom, a picture]" to occur. Thus the sentence with a non-progressive form can be said to occupy the integral part of the time interval necessary for the whole of the event to occur, both its initial and final points included.

The aspect markers, designating either a partial event or a whole event, combine with the aktionsarts to produce the fundamental part of the temporal properties of the events sentences designate. Since aktionsarts are most generally characterized as designators of the types of partial events, it is theoretically profitable to consider the aspect markers to be a pair of forms to express partiality or non-partiality (wholeness) of events.

We now go on to a formalization of the temporal properties of the aktionsarts and the aspects in the next chapter.

## 2. Formalization of aktionsarts and aspects

2.1. Graphic expressions of aktionsarts

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[2] This is a very roughly formalized version of the events which the sentences (3a) and (3b) denote. The principal point is that the predicate is "paint", the subject is "Tom" and the object is "a picture" (one indefinite entity designated by the noun "picture").

Let there be a plane with two axes- the x-axis and the y-axis: the x-axis represents time and the y-axis represents distance.

As for the perfect homogeneity verb, events designating existence, possession, relation, quality etc. exclude movements in space or changes of internal or external qualities. In terms of graphical expression, lack of movement in space means constant distances from the x-axis. When we take the x-axis as the reference line to estimate the degrees of changes, lack of changes of qualities is understood likewise as keeping constant distances from the reference line, that is the x-axis. These numerical properties of the events that perfect homogeneity verbs denote are algebraically expressed by way of the constant numerical value of the y-coordinates of the points, thus expressing lines parallel to the x-axis (Graph 1).

The partial homogeneity verb designate events of moving in space, like walking, flying, swimming, turning, dancing etc. In these events, the accumulated distances or lengths increase as the moving activities continue. Thus the events of this type are algebraically represented as linear functions. Setting the starting point of the movements at the origin of the coordinates, we get a graph like Graph 2.
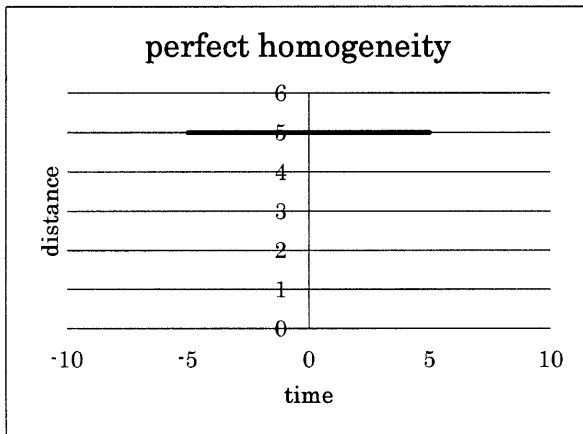

Graph 1   trajectory for perfect homogeneity verbs
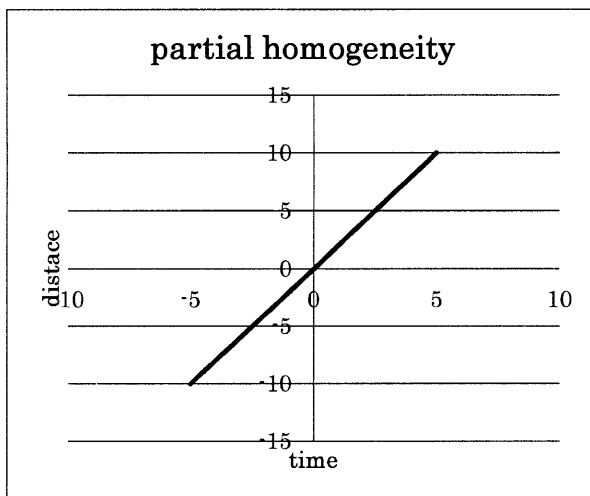
Graph 2   trajectory for partial homogeneity verbs

The events designated by the heterogeneity verbs, like pushing a cart, building a house, running 10 kilometers etc., are characterized by the fact that the quantity of the covered distances or the accomplished works at one moment of the interval corresponds to the length of the line representing some linear function measured from the starting point to the final point.

When the linear function is $y = ax$, the covered length is calculated as $\sqrt{(a^2 + 1)x^2}$. Thus the graphical representation of the events designated by the heterogeneity verbs is as the following:
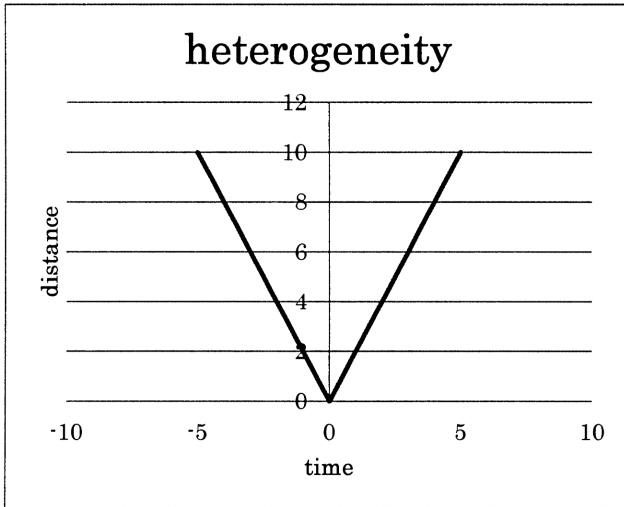
heterogeneity

Graph 3　trajectory for heterogeneity verbs

Punctual verbs denote events that take place at a moment on the timeline. Since the places they occupy can be at any position on the x-y plane, the events of this type are graphically represented as points randomly positioned on the plane (Graph 4).
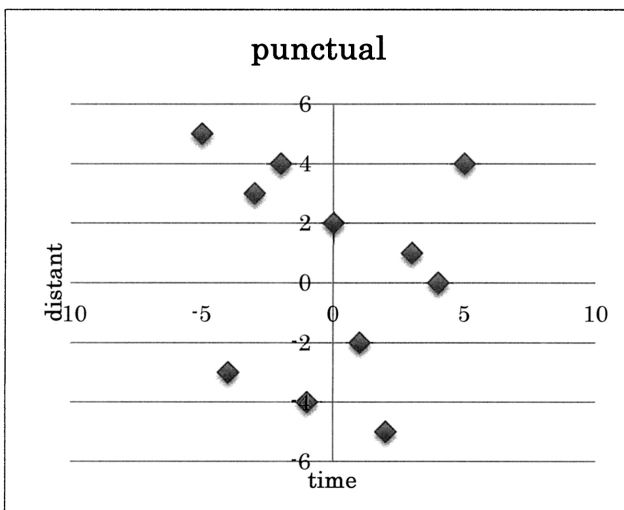
punctual

Graph 4　trajectory for punctual verbs

2.2. Algebraic expressions of the aktionsarts

The graphs shown above represent the temporal cores of the designated events and the content of the cores are further restricted or modified by other components of the sentence, such as tense-aspect markers, temporal adverbs, singular or plural forms of nouns etc. In order to make clear the determining process of the overall temporal properties of events, it is necessary to make algebraic version of the graphically represented temporal cores of the events.

For this purpose, we introduce the following notations:

C: formulaic expression of the aktionsarts

C_m: formula for the perfect homogeneity verb

C_p: formula for the partial homogeneity verb

C_t: formula for the heterogeneity verb

C_u: formula for the punctual verb

T: formulaic expression of the tense morpheme

A: formulaic expression of the aspect morphemes

P: formulaic expression of the temporal property of events

Let i and f be the two points on the time axis, i being the initial point of an event and f being the final point. Then the temporal cores of events are represented as the following functions:

$$_m{:}\, y = l \ (l \ is \ a \ constant)[i \leq x \leq f]$$
$$C_p{:}\, y = px \ (p \ is \ a \ constant)[i \leq x \leq f, \ i \neq f]$$
$$C_t{:}\, y = \sqrt{(p^2 + 1)x^2} \ (p \ is \ a \ constant)[i \leq x \leq f, \ i \neq f]$$
$$C_u{:}\, x = u, y = v \ (u \ and \ v \ are \ constants)$$

2.3. Formalization of tenses

T is a function to place temporal cores on a fixed time interval belonging to the time axis. On the time axis, the absolute reference point is the present (of which the value is 0) and the part left to the present is the past (the value is less than 0), while the part right to the present is the future (the value is greater than 0).

When a language has three tenses, namely the past, the present and the future, like English, French and others, T places the time interval of an event on a part prior to the present or a moment equal to the present or a part posterior to the present. This tense system is, as it were, ideal because, the present moment being the absolute reference time for an arbitrary language user, it is cognitively preferable for three different tense markers each to indicate three different parts composing the time axis.

In this case, T is a function to assign the cores of the events to one of those three parts on the time axis defined as above. Thus this type of T is composed of three different functions: T_b, T_p and T_a. They are formulaically expressed as follows:

$$T_b{:}\, f(C)[i \leq x \leq f < 0]$$
$$T_p{:}\, f(C)[x = 0]$$

$$T_f: f(C)[0 < i \leq x \leq f]$$

C is a function of x to determine the temporal core of the events.

English is a language having a morphologically and functionally distinct "present perfect" tense[3]. The function T_c it represents is expressed as follows:

$$T_c: f(C)[i \leq x \leq 0 \leq f]$$

There are many languages, like Japanese, Korean, Russian, German etc., having no future tense, thus their tense system being composed of the past and the non-past tense. In these languages, the functions (T_b for the past tense and T_n for the non-past tense) these tense forms carry out are formulaically represented as follows:

$$T_b: f(C)[i \leq x \leq f < 0]$$
$$T_n: f(C)[0 \leq i \leq x \leq f]$$

2.4. Formalization of aspects

The aspect is a function A (A_c or A_o) such that it presents the event as a whole event or a partial event. From the viewpoint of the property of the time interval, a whole event occupies a closed interval, while a partial event occupies an open interval. Any interval the aspect forms indicate can occupy an arbitrary place on the time axis, which property of the aspect forms is quite different from that of the tense forms that place the time intervals relatively with the present moment absolutely determined.

The functions that the aspect forms refer to are represented as follows:

$$A_c: f(C)[i < x < f]$$
$$A_o: f(C)[i \leq x \leq f]$$

i is the initial point and f is the final point of the time interval the event occupies.

3. Composing process of the temporal core, the tense and the aspect

Composition of the temporal cores (aktionsarts) and of the tense and aspect functions induces the overall temporal properties of the events represented by sentences. First the stem of the predicate presents the function corresponding to its proper temporal core, second the tense function determines the time interval for the temporal core to be placed and third, the aspect function establishes whether the interval is a whole or a part, that is, a closed interval or an open one. Since the tense function and the aspect function are independent of each other, the exchange of the second and the third stages produces no difference.

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[3] Comrie (1976) affirms that English present perfect doesn't belong to the generally accepted tense forms. In fact the function of the form is different from those of the other proper tense forms in that besides the function of indicating a past time interval, "present relevance" is required for its appropriate use. Nevertheless it is true that the event expressed by the present perfect form occupies a time interval from a point prior to the present up to a point infinitesimally close to the present. And this temporal property properly qualifies the English present perfect as a tense.

The composing process of the temporal functions is schematically formulated as follows:

$$P = T \circ A \circ C$$

Suppose C is a partial homogeneity, A is a part and T is the past, then these functions are combined in the following way.

$$C_p: y = ax$$
$$A_c: f(C)\,[i < x < f]$$
$$A_c \circ C = ax\,[i < x < f]$$
$$T_b: f(C)\,[i \leq x \leq f < 0]$$
$$P = T_b \circ A_c \circ C = ax\,[i < x < f0]$$

The temporal property designated by this formula is that a part of an event with partial heterogeneity takes place on a time interval prior to the present moment.

Now we will give some examples of the composing process of the temporal functions to establish the final temporal property of the sentence. Let us consider the following sentences:

(4) a. Tom is in his room.

b. Betty took a train to Boston.

c. Jack has been reading a book.

4a.

temporal core $C_m: y = l\,[i \leq x \leq f]$

aspect $\quad A_c: f(C)\,[i < x < f]$

tense $\quad T_p: f(C)\,[x = 0]$

temporal property

$$C_p \circ Ac = [(i, l), (f, l)]$$
$$P = T_p \circ A_p \circ C_p = [(i, l), (f, l)]\,[x = 0] = [0, l]$$

Since the temporal core of a perfectly homogeneous event allows $i = f$, the formulaic expression P is appropriate, which means that a partial event, which is equal to the whole event, takes place at the present moment.

4b.

temporal core $C_t: y = \sqrt{(p^2 + 1)x^2}\;[i \leq x \leq f,\; i \neq f]$

aspect $\quad A_c: f(C)\,[i < x < f]$

tense $\quad T_b: f(C)\,[i \leq x \leq f < 0]$

temporal property

$$A_c \circ Ct = \sqrt{(p^2 + 1)x^2}\;[i < x < f]$$
$$P = T_b \circ C_t \circ A_c = \sqrt{(p^2 + 1)x^2}\;[i < x < f < 0]$$

This temporal property means that at some time interval prior to the present moment, the whole event of Betty's taking a train to Boston took place. Let p be 100, i be -5 and f be -2, then the covered length is

$\sqrt{(10^4 + 1)((-2)^2 - (-5)^2)^2} = \sqrt{3610361}$ (approximately 1900).

4c.

temporal core $C_p: y = px$ (p is a $constant$)$[i \leq x \leq f, i \neq f]$

aspect $A_0: f(C)$ $[i \leq x \leq f]$

tense $T_c: f(C)$ $[i \leq x \leq 0 \leq f]$

temporal property

$A_o \circ C_p = px$ $[i \leq x \leq f, i \neq f]$

$P = T_c \circ A_o \circ C_p = px$ $[i \leq x \leq 0 \leq f]$

The temporal property means that a part of the event "read [Jack, a book] " takes place at an open time interval including the present moment. Since the interval is open, it remains undetermined whether the event ends just at the present moment or it continues until after the present moment. Thus the sentence can mean both Jack's finishing reading a book just at the present moment and his finishing it after a time posterior to the present moment.

4. Explanation of the understood temporal properties of sentences

The formal expressions thus far presented of the temporal properties of events couldn't be considered useful without being qualified as providing a proper means to explain how the real understanding of the temporal properties is acquired by composing the temporal meanings of the morphemes in the sentences. In order to verify its usefulness, we pick up some sentences in Japanese and explain in a formal way how their temporal meanings are obtained.

Let us consider the following sentences:

(5) a. Ken-wa ringo-o tabe-ru.

     proper noun-theme   apple-object   eat (non-past, whole)

     "Ken eats an apple."

   b. Kinoo-kara ame-ga huQ-teiru

     yesterday-since rain-subject fall (non-past, part)

     "It has been raining since yesterday."

The obtaining processes of the temporal properties are as follows:

5a.

temporal core $C_t: y = \sqrt{(p^2 + 1)x^2}$ (p is a $constant$)$[i \leq x \leq f, i \neq f]$

aspect $A_c: f(C)$ $[i < x < f]$

tense $\qquad T_n: f(C)\ [0 \leq i \leq x \leq f]$

temporal property

$A_c \circ C_t = \sqrt{(p^2 + 1)x^2}\ \ [i < x < f]$

$P = T_n \circ A_c \circ C_t = \sqrt{(p^2 + 1)x^2}\ \ [0 \leq i < x < f]$

Intuitively, the sentence is understood as taking place in the future, not at the present moment. When we consider the formalized temporal property, the value of x necessarily being greater than 0, the value of $\sqrt{(p^2 + 1)x^2}$ must also be greater than 0, which means that the time interval the event occupies is placed at a time point posterior to the present moment, namely in the future. Thus although the tense form seem to allow the corresponding event to take place either at the present moment or in the future, the interval that the formalized temporal property assigns to the sentence excludes the present moment, which does agree with the intuitional interpretation.

5b.

temporal core $\qquad C_p: y = px\ (p\ is\ a\ constant)\ [i \leq x \leq f, i \neq f]$

aspect $\qquad A_o: f(C)\ [i \leq x \leq f]$

tense $\qquad T_n: f(C)\ [0 \leq i \leq x \leq f]$

temporal property

$A_o \circ C_p = px\ \ [i \leq x \leq f, i \neq f]$

$P = T_n \circ A_o \circ C_p = px\ [0 \leq i \leq x \leq f,\ i \neq f]$

The intuitional interpretation of the event designated by the sentence is that the rainfall began the day before the day of the utterance with its supposed end in the near future. And the formalized temporal property purports that the rainfall occupies the time interval between the present moment and a time point after the present moment. Since the event is supposed to be partial, it can take place at the present moment, in which case its initial point is necessarily placed at a time prior to the present moment, thus indicating that the rainfall began in the past, continuing up to the present moment.

The above formula allows another interpretation that the event occupies a time interval in the future, but it is nevertheless excluded because the phrase "kinoo-kara (since yesterday)" requires that the initial point of the event be prior to the present moment.

5. Conclusion

The factors constituting the temporal properties of events expressed in natural languages, essentially being limited in number and qualitatively rather simple, do not defy formalization in graphic or algebraic terms. And the formalized version of the temporal properties makes clearer how the temporal meanings of the morphemes in sentences are combined to produce the overall temporal characters of sentences, thus enabling us to make substantial explanation of the temporal understanding of the sentences intuitively obtained by the language users. Since rational and logical explanation of the linguistic phenomena is surely the ultimate and proper purpose of any linguistic studies, the formalization presented in this paper with the use of graphic and algebraic expressions will be considered to make a hopeful contribution to the proper development of linguistic science.

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文の時間的特性の形式的記述と説明

町田　健

machidaken@gmail.com

キーワード：　時制　アスペクト　動作態　時間的特性　形式化　説明

要旨

文が表示する事態の時間的特性は、動作態と時制・アスペクト形式の組み合わせによる産物である。時間的特性が得られる過程を説明するためには、事態を構成する時間的要素を正確に記述すると同時に、これらの要素が統合される過程を詳細に解明する必要がある。この目的を適切な形で達成するために、言語研究が期待をもって選択することができる方法の一つとして、形式的表示がある。本稿は、文が表示する事態の時間的な特性が直観的に理解された結果を説明できるようにするための、できるだけ精密な形式化を提示することを目的とする。

（まちだ・けん　名古屋大学大学院文学研究科）