Partial Orderings and Aktionsarten in Discourse Representation Theory

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Abstract

This paper presents an approach to deal with the underspecification of Aktionsarten in German sentences. In German the difference between an accomplishment and the associated progressive state is often not marked on the sentence level. This distinction is important for correctly interpreting texts and for translation into languages which provide morphological markings of Aktionsarten. To maintain compositionality we suggest a two-step analysis of a text with respect to the temporal relations and the classification as events or states. This analysis is guided by the Discourse Representation Theory developed by Kamp and makes use of world knowledge and an inference component.

The problem of classification can be reformulated as the problem of finding an embedding function f from the representational entities onto the domain of a model. The models we use are structures built from intervals of time, events, and individuals. Considering intensional models of this type will allow us to give truth-conditions for progressive states related to corresponding accomplishments. We restrict ourselves to progressive states of intensional actions and use the beliefs of the agent.

1) Introduction:

The influence of the criterion "Aktionsart" with respect to the temporal relations of temporal entities often seems to be overemphasized. On the one hand the correct classification is a problem, on the other hand, it seems that in more cases than assumed the influence of world knowledge is necessary to disambiguate the temporal relations.

In this paper an approach is presented based on a two-step analysis of a text. The first step consists in constructing a partial ordering on the basis of an approximate classification of the temporal units on sentence level, using the framework of Discourse Representation Theory /Kamp 1981a/. In the second step we try to obtain possible linear readings, using background-information, provided by a database, and an inference component that is an extended version of the "event-calculus" /cf.Kowalski,Sergot/.

The subdivision into two steps enables the temporal resolution component to work without a great number of inferencing processes. This contributes to a more modular-like structuring of the natural language processing-system. The goal is to represent ambiguous readings as such.

The progressive state reading of an accomplishment leads to the problem called 'imperfective paradox'. Using the beliefs of the agent we try to give a solution for the subclass of intentional actions. The problem here is to deal with the time dependency of the content of someone's belief.

2) Partial Event-Structures

The starting point of this paper is the conviction, following Kamp and others, that within the temporal units, events are primordial, and time is abstracted from them. The construction of pure temporal units can be based on the ultra-filter-construction introduced by Wiener /cf.Kamp 1979,1981/ along with the following axioms:

A1 \( \forall e_1,e_2 \space e_1 < e_2 \rightarrow \neg e_2 < e_1 \)
A2 \( \forall e_1,e_2,e_3 \space e_1 < e_2 \land e_2 < e_3 \rightarrow e_1 < e_3 \)
A3 \( \forall e_1,e_2 \space e_1 o e_2 \rightarrow e_2 o e_1 \)
A4 \( \forall e_1 \space e_1 o e_1 \)
A5 \( \forall e_1,e_2 \space e_1 < e_2 \rightarrow \neg e_2 o e_1 \)
A6 \( \forall e_1,e_2,e_3,e_4 \space e_1 < e_2 \land e_2 o e_3 \land e_3 < e_4 \rightarrow e_1 < e_4 \)

Including the axiom of linearity

A7 \( \forall e_1,e_2 \space e_1 < e_2 \rightarrow e_1 o e_2 \land e_2 o e_1 \)

other relations like 'subset' or "temporal equivalence" can be defined out of these basic relations. This shows the fundamental significance of the relations < and o.

The addition of new events can allow a more accurate statement of the temporal relations. If we start with an uttered relation of vague simultaneity between two events \( e_i \) and \( e_j \) expressed by \( e_i o e_j \), and if it becomes clear from later passages of the text that there are events \( e_k \) and \( e_l \) with \( e_k < e_l \) and \( e_j o e_l \) and \( e_k o e_i \) we can deduce by the Wiener construction, that the event \( e_i \), seen as punctual at the beginning, consists of at least three moments of time \( t_1, t_2, t_3 \). Thus the internal structure of such events can become more elaborate as the text proceeds. In addition we can specify with greater precision the relation between events. In the case of \( e_1 \) and \( e_2 \) we are now able to conclude, that the overlap of the beginning has to be understood as a subset-relation between \( e_2 \) and \( e_1 \).

In the following we will make use of this conception within the definition of our models for representations of texts.

The Aktionsarten, redefined by Vandler, have frequently served as criterion to correctly construct time-structures from natural language texts /cf.Dowty 1986,Haunrichs,Partee/.

The opinion is not tenable however that telic events (accomplishments, achievements), in the absence of temporal adverbials, shift the reference time for new temporal units forward, and that activities, or so-called atelic events, and states do not. This is often argued in the literature.
Example 1:
(e₁₁) John wrote a program. (e₁₂) He logged in,
(e₁₃) opened his file and
(e₁₄) began writing and correcting by using his papers.

Example 2:
(e₂₁) Yesterday a lot of things happened.
(e₂₂) John bought a bicycle,
(e₂₃) Mary demolished Stanley’s microwave oven.
...
In example 1, e₁₃ < e₂₃ are internally ordered subevents of e₀. In example 2, no obvious ordering between e₁ and e₂ exists.

Without inferring and using a detailed analysis of discourse functions as “continuation” or “elaboration” we can not establish the right ordering relations for such cases.

It is even harder to state correctly temporal relations within a compositional approach:

Example 3:
(e₃₁) John took the plane to Frankfurt.
(e₃₂) Then he took the train to Stuttgart.
(e₃₃) As he’d had nothing to eat since breakfast
(e₃₄) he bought a sandwich at the station.

a) (e₃₅) Then he boarded the train.

b) (e₃₆) Then he phoned his wife to say that he’d arrived,
(e₃₇) before taking the true hour.

Only when processing the fourth sentence of example 3 do we discover that e₂ is an elaboration of e₁ in the case of a), whereas in b) e₂ is a continuation of e₁.

Thus what we should do in the first step of the analysis is to construct an underspecified ordering hoping that in the second step, on the basis of the representation of the whole text, we can refine the conditions. We restrict ourselves to cases as in example 1 and 3, because here it suffices that one reference point is provided by the representation of the preceding text.

To represent the ambiguity between continuation and elaboration we need a relation “not-before”. However to define “not-before” as a transitive relation the disjunction of < and o (<;o) is not sufficient. This becomes clear from examples 1 and 3 which would then be expressed by the following:

\[ e₁ < e₂ \land e₂ < e₃ \land e₃ \not< e₂ \land e₂ \not< e₁ \]

Because o is not transitive, for an admitted reading "e₁ o e₂ o e₃" (which would be true in cases where e₁ is a subevent of e₂ and e₂ a subevent of e₃ and so on) one cannot exclude the possibility that "e₃ < e₁", which is surely not the case for such episodic readings.

Example 4:

\[ \begin{array}{cccc}
e₁ & \cdots & e₂ & \cdots & e₃ \\
\end{array} \]

Thus we have to require:

\[ \forall e₁, e₂ : (e₂ \not< e₁) \Rightarrow (\forall e₁, e₂, e₃ : (e₁ o e₂ o e₃ < e₁ < e₂ < e₃)) \]

This suffices for transitivity as easily can be shown.
\( x \in \text{Ach} \)  
\[ \star \]  
\( \exists_2 \ o \ x \ & (\ (x \ y \ L \ P(T) \ (x < y \ L \ o \ x \ y)) \)  
* The secondary events are considered as atomic:

\( \forall x \in \text{Seccv}, \exists_2 \ x \in \text{U} \ U \ P(T): \ (y \ y \ L \ x \ x \ y \ y) \)  
The axioms A1 - A6, extended to all temporal units of the domain, hold for the relations \(<\), such that it follows, with the inclusion of the linearity axiom:

A7 \( \forall x \in \text{Seccv} \in \text{U} \ U \ P(T): \ (x < y \ L \ y \ y < x) \)  
\( o \) has the characteristic of being an equivalence relation, restricted to the secondary events.

One can thus define:

\( \forall x,y \in \text{Seccv} : x \ y \ L \ y \ y \ L \ x \ y \)  
This allows the abbreviation \( x < y \) for elements of \( \text{Seccv} \) with \( x < y \) or \( x = y \).

\* \( F \) is an interpretation function, such that

\( F \) assigns every n-ary relation \( R \) a function over \( P(T) \), which assigns every \( i \in P(T) \) a subset of \( U^n \).

\* \( G \) assigns every n-ary relation \( R \) a set of \( n+1 \)-tupels out of \( \text{End}^n \).

\* \( b \) is a function which assigns in a one-to-one-correspondence every state \( s \in S \) a pair \( (x, y) \), whereby \( x \) represents a progressive variant of \( R \).

In the addition of the following correlation principle should hold:

For every \( n \)-ary verb \( R \) and every \( n+1 \)-tupel \( (x, y) \in G(R) \) there exists a state \( s \in S \) and an interval \( i \in P(T) \) such that \( b(s) = x \) and either \( i \in d(e) \) or \( i < d(e) \), whereby \( R' \) represents the progressive variant of \( R \).

On the other hand, there should exist for every \( R' \), which is the progressive variant of an \( R \) and which is assigned an \( s \) by \( b \), an \( n+1 \)-tupel \( (x, y) \in G(R) \) with the corresponding ordering and individual relations.

In the system proposed here, a narrative text without any additional specifications which includes a series of events \( e_1 \in \text{Acc}, e_2 \in \text{Ach}, e_3 \in \text{Acc} \) would be assigned the following semantic representation:

\[
\begin{align*}
\text{start}(e_1) \quad \text{end}(e_2) \\
\text{start}(e_2) \quad \ldots \quad \text{mod}(e_2) \quad \ldots \quad \text{start}(e_3) \quad \ldots \quad \text{end}(e_3)
\end{align*}
\]

Thus, the underspecification which is necessary in examples such as 1 and 3 is maintained without the side-effect of example 4.

More exact relations can be established in a second step, using pragmatic knowledge, which completes the structure. In the case of example 2 we assume an indicating which does not allow an internal ordering.

An advantage of this representation, using secondary events, for underspecified texts, over a representation with differentiated ordering relations, such as Allen's internal structures (cf. Allen), is, for example, its notational efficiency:

If \( e_1, e_2 \in \text{Acc} \), then the following holds:

\[
\text{start}(e_2) \ L \text{start}(e_3) \quad \text{is equivalent to} \quad e_1 \ (\ \\
\text{start}(e_2) \ L \text{start}(e_3) \ L \text{end}(e_1)) \ L \text{end}(e_2)
\]

Using the further restriction

\[ \forall e \in \text{Ach}, e_2 \in \text{Seccv}: \quad \text{end}(e_1) \ L \text{start}(e_2) \ (\ (y \ y \ L \ x \ y) \ y \ y \ L \ x \ y) \]  
one can show easily that within the event substructure of the extended point-event structure the relations that Allen uses can be defined in terms of \( o \) and \(<\) such that a relation of isomorphy holds between such extended event structures and Allen's internal structures. (In general this is not the case for the original event structures.)

3) The imperfective paradox and the ambiguity of the Aktionsarten in German

No attempts to solve the paradox that I am familiar with have been able to reduce the validity of a sentence in the progressive form to the validity of the same sentence without a progressive, which was the intent.\(^1\)

Moens and Steedman, with their aspectual net, have proposed a solution in which progressives are only generated from the activity readings of events. I will adopt this view to a certain extent, but will take it one step further, by bringing in beliefs, in order to create the possibility of reestablishing a direct relation at least for some kinds of accomplishments.

The basic idea is that it is often only on the level of a text that a hearer can decide whether the culmination of an accomplishment, which has been introduced by a progressive, has actually been reached. Some texts will leave this decision open, others will force the existence of a culmination, and still others will force the nonexistence of a culmination.

Especially in this last case, it is necessary to question the justification of the use of the progressive state for an accomplishment: how do we know the goal of an action if it is not attained? These possible characteristics of a text should be reflected by the different possibilities of assigning an embedding function relative to a DRS in a model \( M \).

We therefore require for a function \( f \), which maps discourse referents of a DRS \( K \) onto entities in an expanded point-event structure with a domain of individuals, in addition to the usual features (cf. Ryle), the following:

\[
M \models (\text{start}(e) \ L \text{end}(e) \ (\ (y \ y \ L \ x \ y) \ y) \ y \ L \ x \ y) \]  
and either \( \text{end}(e) \ L \text{end}(e) \) or \( \text{end}(e) \ L \text{end}(e) \) in \( \text{Dsm} \) or \( \text{end}(e) \ L \text{end}(e) \) in \( \text{Cal} \).

In addition the DRS construction algorithm must contain the rule:

For all \( e \in \text{Acc}, e' \in \text{U} \ U \ P(T): \ (\text{end}(e) \ L \text{end}(e') \ L \text{end}(e) \ L \text{end}(e')) \]  

If one requires, as in the correlation principle, that every state introduced by the progressive of an accomplishment verb be contained by an event, then the question whether \( e \) has a culmination (that is, represents a true accomplishment) or just a stop-point (that is, corresponds to the activity reading of an accomplishment), is transformed into the question of the existence of the corresponding \( f \).

\(^1\) Compare to this and the analogous approach in (Scholz). In a subsequent paper we want to generalize the result with respect to the whole temporal substructure of an extended point-event structure.

\(^2\) Dowty's attempts using "inertia worlds" seem to lead to difficulties with respect to the correct non-subjective definition of the notion of an inertia world (cf. Dowty 1970).
On the other hand, the question whether a corresponding expression in German is to be read as the progressive of an accomplishment or as a real accomplishment will not necessarily be decided on the sentence level. We enter start(e) < end(e) and make the interpretation of end(e) depend on the possibility of finding an embedding function f.

Example 5: (c1) Hans überquerte die Straße. (Hans crossed/was crossing the street) (c2) Ein Lorry schoss aus auf ihn zu und (A lorry approached him at speed and) (c3) Gegen die ihn auf der Höhe des Mittelstreifens. (ran him over in the middle of the road.) (c4) Er starb auf der Stelle. (Death was instantaneous.)

In this constellation, the compositionally constructed $c_1 \in Acc$ cannot be truly interpreted as an accomplishment since Hans never arrived at the other side of the street. A simplified representation in our system would give the following:

$$\begin{align*}
\text{end(e}_1) & \land \phi \\
\text{start(e}_1) & \land \phi \\
& \ldots \\
\text{end(e}_4) & \land \phi \\
\end{align*}$$

Incorporating a spatial-temporal inference component (in the second step of the analysis) which uses rules that deal with presuppositions and resulting states with respect to events and states, one would get, in pseudo-prolog notation:

$$\begin{align*}
l(e_1, h, s, \text{street}) & \land e_1 \in \text{Cul} \rightarrow l(e_2, h, s, \text{street}) \\
l(e_2, h, s, \text{street}) & \land e_2 \in \text{Cul} \rightarrow l(e_3, h, s, \text{street}) \\
l(e_3, h, s, \text{street}) & \land e_3 \in \text{Cul} \rightarrow l(e_4, h, s, \text{street}) \\
\text{true}(\text{end(e}_4), \text{exists(h)}) & \land \text{true}(\text{start(e}_4), \text{exists(h)}) \\
\end{align*}$$

On the basis of these facts one can conclude that no linear ordering of the secondary events can exist if $\text{end(e}_1) \in \text{Cul}$ holds. Therefore we make use of an extended version of the event-calculus by introducing for each linear reading which is to be tested "auxiliary" events to get endpoints for the introduced states if needed. If such events contradict with respect to a story an assumption which one could call the relevance-principle, the proposed linear reading is rejected. This relevance-principle for instance would predict that in a story in which the agent crosses the street but is nevertheless later located in the street, an event of reentering the street must be considered.

Thus, every embedding function $f$, on the basis of the appropriate axioms, must map $\text{end(e}_1)$ onto an element from $\text{Stop}^M$. $e_1$ is interpreted as a non-real accomplishment and this part of the text is no longer ambiguous. When translating this representation into a natural language, the corresponding state-marker and not the corresponding event-marker must be considered.

4) Intensional model of a DRS

Although the correlation principle implies a relation between a sentence with the progressive form and the same sentence without, it also makes dependent on $f$ the question of whether the corresponding event to a progressive form of an accomplishment can be read as a real accomplishment or not.

If not, one must ask according to which criteria the special determinability of assertions about accomplishments is justified, since without the possibility of checking the result, the descriptions of progressives such as:

Example 6:

a) "Hans war dabei auf den Berggipfel zu klettern".b) "Hans war dabei auf die Hütte unterhalb des Gipfels zu klettern."

in case the corresponding events are not completed, collapse into the description of a perception of an activity: "Hans kletterte".

What are the criteria for considering one state to be fulfilled at time $t$ and the other not? It seems to me that one possibility of evaluating such cases could consist in referring to beliefs. There is no doubt that not all accomplishments involve agency, and even in the case of agency there is not always intentionality by the agent (cf. Dowty's notion of 'controllability'). But on the one hand intentionality and associated activity can serve as a sufficient condition for the validity of a progressive state. On the other hand, in other cases, the introduction of beliefs can serve to represent expectations of the speaker or mentioned protagonists connected to the introduction of such progressive states. Thus we get at least a further instrument to represent ambiguous readings. Our aim is not to provide the correct truth-conditions for unintentional cases. Here further research is needed. We restrict ourselves to the description of cases as in example 6 and we will concentrate on the notion of belief in a framework where time comes into play.

For cases as in example 6 we require that: 'Hans ist dabei auf den Berggipfel zu klettern' be true at $t$ if an activity $e$ of climbing by Hans in the direction of the peak exists where $e \in C$. and if Hans has the intention of climbing the mountain at $t$, i.e. in the "belief state" of Hans at $t$ there exists an event $e$ which he wants to accomplish.

A DRS-Notation:

| $u$ | $v$ | $s$ | $s'$ |
|-----|-----|-----|-----|
| Hans(u) | Berg(v) | From klettern_auf(u,v) | klettern_auf(1,r) |
| $p$ | $p'$ | believe(u,p) | believe(u,p) |
| $n$ | $n'$ | $n$ | $n$ |
| $r$ | $r'$ | $r = v$ | $r = v$ |
| $s(c)$ | $d(s')$ | $d(s')$ | $d(s')$ |
For the interpretation of such DRS's it is useful to expand the concept of a
DRS model. Extending the model of /Asher/ we define:

Intensional point-event structure with a domain of individuals:

\(< w, n, w, c, r, w, K, K', K'' >\)

The following holds:

* \( W \) is a set of worlds
* \( D = \{ D_w : w \in W \} \)
* \( D_w = < E, T, d, U, \langle r, \text{start}, \text{end}, S, b_N \rangle >, K, K', K'' > \)

For every \( w \in W < E, T, d, U, \langle r, \text{start}, \text{end}, S, b_N \rangle >, w \) is a point-event structure
with a domain of individuals and the corresponding conditions.

\( K \) is a set of DRSs.

\( K' \) is a set of "delineated" DRSs.

\( K'' \) is a set of "predicative" DRSs.

(For our purposes \( K' \) of interest. \( K \) and \( K'' \) are mentioned only for the
sake of completeness).

\( G \) maps every relation \( R \) onto a function, which assigns to every \( w \in W \) a
function which assigns to every \( i \in P(T)_w \) a subset of

\( \{ U \times \text{powerset}(K') \} \).

\( F \) maps "believe" onto a function which assigns to every \( w \in W \) a
function which assigns to every \( i \in P(T)_w \) a subset of

\( \{ U \times \text{powerset}(K') \} \).

\( f \) is an embedding function of a DRS \( K \) in an intensional model if
\( f \) maps every individual reference marker of \( U_k \) onto elements of \( U \times U' \),
every event reference marker of \( U_k \) onto elements of \( U \times E' \),
every state reference marker of \( U_k \) onto elements of \( U \times S' \),
every DRS reference marker of \( U_k \) onto elements of \( K \),
every n-place condition reference marker of \( U_k \) onto \( n \)-ary predicative
DSR's in \( K' \),
every belief reference marker of \( U_k \) onto sets of "delineated DRS's" in \( K' \).

The essential but simplified principle is to be described as follows:

For a more detailed review compare the basic model in /Asher/ where,
in particular, the function \( H \) is defined along with the remaining truth
conditions.

5. Conclusion:

The system considered here allows a solely partial ordering of events and
states on the representational level, which can be completed on the basis
of world knowledge stored in a data base, with respect to the ordering and
the classification into Aktionsarten. The compositionality principle for the
construction of a semantic representation can thereby be maintained.
Ambiguous readings are kept as such, impossible readings are rejected.
The expansion to an intensional model for DRS's not only would permit in
a certain way the restatement of the relation between some kinds of
accomplishments and the corresponding progressive states, but it also
would allow, through the use of the belief predicate, an extended version
of the theory to correctly represent ambiguities such as is made clear in
the following examples through the use of different indices.

Example 7:

"Mary saw Oswald shoot Kennedy"

a) Mary saw Oswald/Mary shoot Kennedy/Mary

b) Mary saw /Mary shoot Kennedy/Mary Oswald/speaker

a) and b) are to be represented by different instantiations of the arguments
for the predicate "believe". A further possible expansion, also
relating to incomplete accomplishments, is the incorporation of unfinished
objects.
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