

ÉTUDES COGNITIVES

STUDIA KOGNITYWNE

ÉTUDES COGNITIVES

7

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Sławistyczny Ośrodek Wydawniczy
Instytut Sławistyki PAN
Pałac Staszica, ul. Nowy Świat 72, 00-330 Warszawa
tel./fax [+48] 22 826 76 88 tel. [+48] 22 827 17 41
sow-ispaw@wp.pl www.ispan.waw.pl

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MOT DE LA RÉDACTION

Le Comité de Rédaction de *Studia Kognitywne / Études Cognitives* se compose de 5 membres : 2 Français et 3 Polonais.

La rédaction scientifique de *Studia Kognitywne / Études Cognitives* reflète non seulement la collaboration internationale entre les Académies et les Universités, mais aussi le caractère interdisciplinaire de l'équipe de rédaction.

Dans le Comité de rédaction de *Studia Kognitywne / Études Cognitives* la France est représentée par les professeurs J.-P. Desclés et Z. Guentchéva.

J.-P. Desclés est logicien, mathématicien et informaticien. Il s'occupe de l'analyse des aspects cognitifs de la langue naturelle et les étudie de différents points de vue, dont le point de vue formel et informatique. Z. Guentchéva s'intéresse à la linguistique générale et à la linguistique slave.

Du côté polonais participent aux travaux de la rédaction W. Banyś — romanisant à l'Institut d'Etudes Romanes de l'Université de Silésie, S. Karolak — slavisant et romanisant et V. Koseska-Toszewa — slavisante et rédacteur en chef de la Revue, tous les deux représentent l'Institut d'Etudes Slaves de la PAN (Académie Polonaise des Sciences).

A l'élaboration de *Studia Kognitywne / Études Cognitives* ont régulièrement participé jusqu'à présent A. Włodarczyk (Lille) — japonisant et informaticien et H. Włodarczyk (Paris IV) — slavisante, ainsi que A. Mazurkiewicz — informaticien et mathématicien de l'Institut des Fondements de l'Informatique de la PAN.

La préparation de *Studia Kognitywne / Études Cognitives* est possible grâce à la contribution financière du C.N.R.S, des Universités Paris IV et Paris VII, de l'Université de Silésie, de l'Académie de Pédagogie de Kraków, de l'Universita degli Studi „G. D'Annunzio“ di Chieti (Italie) et de l'Institut d'Etudes Slaves de la PAN.

Il suffit de visiter le site:

<http://www.ispan.waw.pl> → [Periodyki] → [Studia Kognitywne],
pour s'assurer, d'après les noms des auteurs apparaissant dans les Tables des matières des volumes successifs.

Nous sommes intéressés par une collaboration plus étendue dans le cadre des études cognitives, entre les linguistes, les logiciens et les informaticiens qui s'intéressent à l'étude des langues naturelles.

Slawistyczny Ośrodek Wydawniczy: [1] <http://www.ispan.waw.pl/60katalog.php>

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NATALIA KOTSYBA

Institute of Slavic Studies, Polish Academy of Sciences
Warsaw

TEMPORAL EXPRESSIONS IN PETRI NETS REPRESENTATION

Introduction

Petri nets, originally devised for informatics needs and introduced in 1962 by [Petri], were proposed in 1986 by [Mazurkiewicz] as a possible formalism for representing temporal and modal meanings of natural languages. Theoretical account of their application for natural languages is presented in detail in Koseska-Toszewa [1996] and other works of that author.

It has been demonstrated efficiently in numerous papers by Koseska-Toszewa and/or Antoni Mazurkiewicz that Petri nets can be a good illustration of the way humans conceptualize what happens around them. The nets help us visualize the core meaning of such semantically complex grammatical meanings as the (Bulgarian) *Perfectum* and other tenses, as well as modality and quantification.

For more than twenty years that Petri nets have been used as a formalism for natural languages (mainly Bulgarian, but also Polish, Lithuanian, and recently — Ukrainian and English), numerous descriptions of various temporal and modal situations have appeared. The most exhaustive and consistent account of temporal-aspectual meanings in Bulgarian and their correspondents in Polish with the help of Petri nets has been given by Koseska-Toszewa (45 Bulgarian and 19 Polish verbal forms have been described) [Koseska-Toszewa 2006, 141-146, 163–165]. Time expressions appear in that and other known to us descriptions as natural accompanying elements of some of those forms but they have not been considered systematically alone or in combination with verbal forms.

It is clear that temporal expressions are connected to the meanings of tenses since the former ones often function as semantic ‘anchors’ (indicators) for the latter ones. Temporal expressions make thus an integral part of the general temporal meaning of a sentence and not only can they be described with the help of Petri nets but also their inclusion into graphical representation of natural language sentences is indispensable in order to represent the sentence meaning more accurately. We will try to prove that there is no essential ontological difference between TIMES and EVENTS (we use here and afterwards the term TIMES to denote meanings

of temporal expressions and EVENTS — the meanings of predicates expressed by verbal forms. The use of capital letters is meant to differentiate them from an ‘event’ as one of the basic elements of Petri nets).

We intend thus in this paper to give a provisional classification of temporal expressions together with their graphic representation by means of Petri nets; to show the ways TIMES are related to EVENTS; to compare Petri nets with other existing methods of temporal meaning visualization (Sowa’s Conceptual Graph Theory, TERQAS project proposals, ter Meulen’s Dynamic Aspect Trees) and to give an outline of how Petri nets can be used for discourse representation.

Temporal lexicon

According to the academic grammar of English [CGEL], there are three basic functions of temporal expressions: to show **when** an event/state happened/held (time position adjuncts), **how long** a state lasted (time duration adjuncts) and **how often** they took place (time frequency adjuncts).

Time **position** adjuncts help identify EVENTS by placing them in time. Point adverbials are the most common ones: *at three o’clock, now*. Time **duration** adjuncts are periods of time like: *for three days, for an hour, during the summer*. Time **frequency** adjuncts are expressions like: *often, always, sometimes*

In order to be able to present them by means of Petri nets, we need first to differentiate between units of time and temporal relations. There are two basic units of time — an instant and an interval. We shall argue further that instants are equal in conceptualization to Petri net events and intervals — to states.

Whether a unit of time is an instant (event) or an interval (state) in a particular context is decided by the choice of a preposition. And the choice of a preposition depends on the lexical semantic quality of a juxtaposed EVENT or TIME. Surely, the division of time used in the natural language is strongly dependent on peculiarities of human perception. Theoretically, it is possible to say *during that moment* but in fact a moment of time is rather treated as an instant — *at this moment*. Longer periods of time have more of a double nature and e.g. *I lived there during the winter*. and *I was there in winter*.

Apart from TIMES and EVENTS, there exists the third important element which shows relations between them. An arrow is one of the basic elements of Petri nets which functions for this purpose. But the relations are not restricted to arrows alone, they can have a more complicated structure and include states and events as well as arrows. In this section we will also try to show that basically those relations are the same between TIMES and EVENTS, and among them.

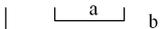
Sometimes EVENTS and TIMES related to them coincide in duration (including punctual activities placed/ mapped against moments of time). Sometimes some of them are longer, i.e. either TIMES become a background for EVENTS or *vice versa*.

In the literature they differentiate only two relations **between instants**: SIMULTANEITY and SUCCESSION.

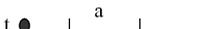
Hamblin (1969) and Allen (1983)¹ introduce 13 irreducible relations **between**

¹We cite here from [Setzer 2001, 18].

intervals. We show them in the table below² omitting the reversals of the first 6 relations³.

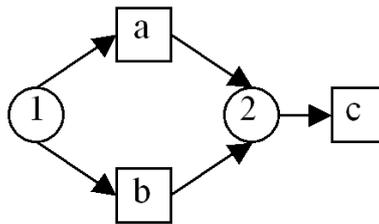
1) a BEFORE b	
2) a MEETS b	
3) a OVERLAPS b	
4) a BEGINS b	
5) a FALLS WITHIN b	
6) a FINISHES b	
7) a EQUALS b	

Finally, there are 5 irreducible relations **between instants and intervals**⁴.

1) t PRECEDES a	
2) t STARTS a	
3) t DIVIDES a	
4) t ENDS a	
5) t FOLLOWS a	

We can see that some temporal relations have a linear nature and some of them need presenting parallel structures. We show below the Petri net way of representing those relations.

Instant-instant relations:



1. event a IS SIMULTANEOUS TO event b
2. event c IS SUCCESSIVE TO event a (and event b).

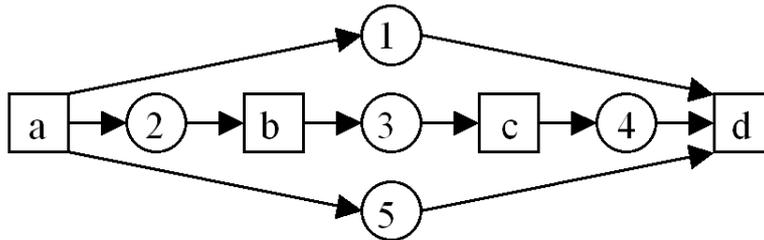
Prepositions of time function to show all these relations. Combining with either instants or intervals, prepositions of time form composite structures that relate to

²Ibidem, based on Galton 1995.

³Those reversals, however, will be of more importance in natural language realizations. Some lexical means express only one way relations.

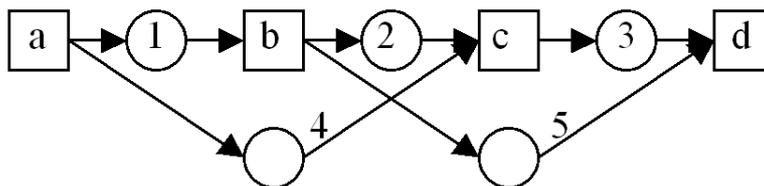
⁴Ibidem, with the same source. There is a mistake in the original version - the names of the relations 1 and 5 have been substituted for each other.

Interval-interval relations:



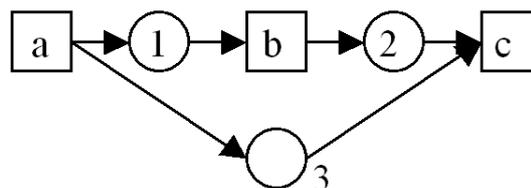
3. state 2 IS BEFORE state 4
4. state 3 MEETS state 2 (also 4::3)
5. state 2 BEGINS state 5
6. state 3 FALLS WITHIN state 5
7. state 4 FINISHES state 5
8. state 1 EQUALS state 5

Overlapping of intervals:



9. state 4 OVERLAPS state 5

Instant-interval relations:



10. event a PRECEDES state 2
11. event a STARTS state 1 (also b::2)
12. event b DIVIDES state 3
13. event b ENDS state 1 (also c::2)
14. event c FOLLOWS state 1

correspondent EVENT (or other TIME) expressions. Time adverbs like *afterwards*, *earlier* have the same function but do not mention the ‘reference’ point explicitly.

We present basic temporal relations and temporal expressions / grammatical structures associated with them in the English language in the following table 1.:

temporal relation	preposition ⁵	adverbial	conjunction	tense (wrt moment of speech)
1. simultaneous	at, on			present
2. successive	before, after			past, future
3. before	before	earlier, then		past
4. meets	in	just	as soon as	present perfect
5. begins				
6. falls within	during, in		while	present continuous
7. finishes				
8. equals	for, throughout, over	for three hours	when, while, as long as	present
9. overlaps				present perfect
10. precedes	before	earlier		past
11. starts	since	recently, afterwards		
12. divides	during, in, on, at		when	present continuous
13. ends	by, until, in	beforehand, formerly	until	
14. follows	after			future

Frequency adverbials like *every day* are connected with quantification and are partially exemplified later. Time expressions of different types can be used in the same sentence, cf. example 5. We illustrate the use of different types of temporal expressions in the part where Petri nets are compared with some of the existing means of visualizing temporality.

Our observations make us think that the nature of TIMES and EVENTS is very similar. Both TIMES and EVENTS can be either states or events in Petri nets. A more important difference is probably between temporal expressions that answer the question *When?* and those answering the question *How long?* In each of the following pairs of sentences the first one concerns temporal relations between TIMES and the second one concerns the same temporal relation between EVENTS.

⁵We present here only those expressions that are normally associated with a certain type of temporal relations without specifying which of the two arguments it refers to. That is why we can see expressions with opposite meanings in the same boxes. Since some of the relations are symmetrical, the same expressions can appear in more than one box.

Monday comes after Sunday.

John always shaves immediately after having a bath.

January begins a year.

His singing wakes me up.

Summer solstice divides an astronomical year into halves.

She always comes in the middle of the lecture.

Petri nets representation will be the same within each pair but different among the pairs. EVENTS can be treated as ‘stuffed’ TIMES. Petri nets allow thus to present a unified treatment of TIMES and EVENTS.

TIMES and tenses

We know that certain temporal expressions and grammatical tenses are incompatible. For instance, the English Present Perfect is not used with expressions like *yesterday, a week ago, last Monday, at four o'clock*, which are reserved for the Past Indefinite [CGEL, 194]. On the other hand, it can be used with *up to now, since x, so far, hitherto* etc. which are incompatible with the Past Indefinite.

We can show with the help of Petri nets the reason of this incompatibility.

The first set of expressions defines time positions that are separate from the moment of speech (‘now’). The second set presents periods of time whose end coincides with the moment of speech. Since TIMES are used to identify tenses, they should either coincide with them on the time axis or include them. In other words, their relations should be either EQUAL(8) / SIMULTANEOUS(1) or STARTS(11), ENDS(13), DIVIDES(12) according to our classification. The moment of speech ‘now’ is excluded from the Past tense meaning and is included into the ‘second set’ expressions, which creates the mentioned conflict of meanings — the spans of TIMES and tenses overlap but the above mentioned conditions are not fulfilled. The same refers to the impossibility of using future time expressions like *tomorrow* with the Past tenses — being divided at least by ‘now’ instant those even do not overlap.

An interesting case is presented by expressions like *this year, today* that can be used both with the Present Perfect and the Past Indefinite. These are time periods which include the moment of speech ‘now’. In the case of the Past Indefinite a different temporal relation is meant, which is AFTER the end of yesterday (last year) AND some time BEFORE ‘now’. In fact, there is an implicit element *earlier* in those expressions when used with the Past Indefinite and that is the key temporal relation. The other part shows temporal limits on the opposite side of the time axis.

Petri nets vs TERQAS format of time visualization

As it has already been mentioned, basic intuition behind the way we chose to apply Petri nets for visualizing temporal relationships is such that periods of time and states described by verbal forms can both be abstracted to States, while moments of time and so-called punctual actions can be abstracted to Events. Some more composite temporal expressions and processes can be seen as combinations of States and Events. States and Events are understood here as Petri nets elements.

The novelty here would be introducing intervals and instants of time into the schemes, as the earlier Petri nets applications for linguistic purposes known to us [Koseska-Toszewa, Mazurkiewicz] concentrated more on temporal-aspectual verbal meanings. Time adjuncts were not included into the schemes⁶, although the theory itself does not exclude such a possibility. The idea of including time adjuncts as well as verbal forms into the schematic representation in order to obtain a complete temporal picture of a sentence proposed by TimeML authors was put at the basis of our approach. The major difference between TERQAS project and the present approach would be the equal treatment of TIMES and EVENTS in our case.

The developers of TimeML (annotation scheme for temporality) single out the following types of temporal relations that can hold between entities: BEFORE, AFTER, INCLUDES, IS INCLUDED, HOLDS, SIMULTANEOUS, IAFTER, IBEFORE, IDENTITY, BEGINS, ENDS, BEGUN BY, ENDED BY [Pustejovsky et al. 2002, 65]. Those relations roughly correspond to the described above ones, although the authors do not differentiate between instants and intervals, combining thus relations 12 and 6, 1 and 8, 3 and 10 from our lexicon into the same types. However, they do differentiate between the reversed versions of those temporal relations, which is essential for accurate annotation of temporality. At the moment we abstract from that differentiation.

Composite structures like punctual adverbials *at three o'clock* express SIMULTANEOUS or IS INCLUDED relation, depending on whether we talk of an event or a state, e.g.:

At three o'clock Peter was taking a bath.

At three o'clock Peter woke up.

Container adverbials like *in three days*, *in a year* express IAFTER relation, which says that something happens immediately after the mentioned period of time ends. Durative adverbials like *for three days*, *for an hour*, *from Monday till Thursday*, *during the summer* express SIMULTANEOUS relation and refer to periods of time and corresponding simultaneous states.

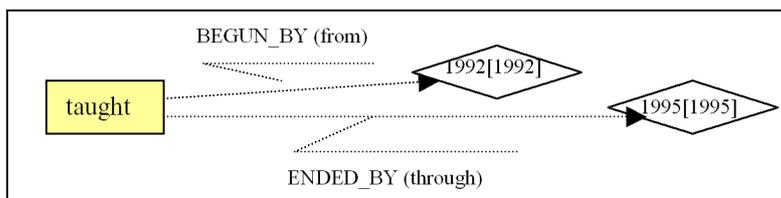
We shall give several examples of graphic representation of the same sentences (temporal situations) using both TERQAS format [Pustejovsky et al., 2002, p. 35]⁷ and Petri nets.

⁶Nominalizations like *explosion* and adjectivizations like *dormant* — deverbatives functioning as predicates — were not considered systematically either.

⁷The sentences that are illustrated are also presented under the original graph.

Example 1.

The TERQAS variant:



John taught from 1992 through 1995.

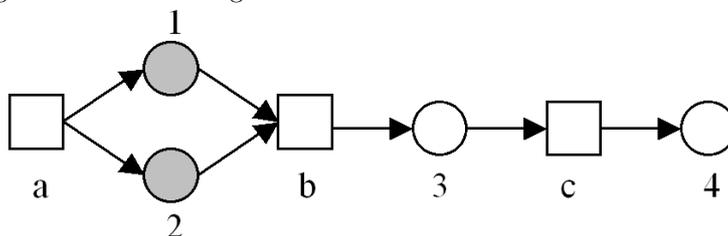


Fig. 3. Petri net representation

Event *a* corresponds to the year 1992, Event *b* corresponds to the year 1995; State 1 is the three year period of time (1992–1995) and it coincides with the period of John’s teaching — State 2. The year 1992 and the year 1995 are seen here as points of time coinciding with the moments when John’s teaching began and ended respectively. State 3 introduces a period of time that held after the end of year 1995 and before some event *c* that initiated the state of speech 4. The latter one is necessary to situate the described EVENT in the past⁸.

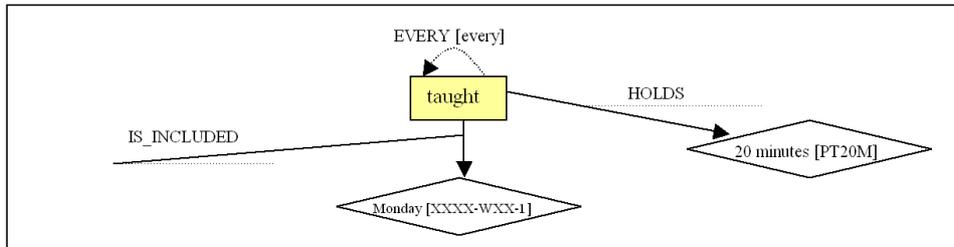
It is not common to consider a year a point of time if we map on it most of the verbs (or predicates, taking it more generally) that exist in our vocabulary. Especially this concerns EVENTS classified as PERCEPTUAL, REPORTING, I.ACTIONS and I.STATES⁹. A year will be rather seen as a period of time in combination with them. When it is mapped to ‘biographical’ verbs, it can be seen as a point of time. This difference is essential because it proves that we cannot classify all time adjuncts into time intervals and time points on the dictionary level, without specifying the kind of a predicate they are mapped on, which is the case with some ontologies (SUMO, ONTOLINGUA as presented in [Pustejovsky et al., 2002, p. 5]). In Petri nets periods and instants of time, as well as EVENTS, are relativized. We can see that Petri nets show events and states in their chronological sequence by means of ordering arrows while in the TERQAS variant this sequence is verbalized.

⁸Since all the situations described further in this article are in the past tense, we do not show states of speech in all cases for the sake of simplicity of presentation. We treat it as a default state that immediately or not immediately follows the last described event. In the case of examples like 2 the whole looped situation is seen as past with respect to the state of speech.

⁹TimeML terminology, [Pustejovsky et al. 2002].

Example 2.

The TERQAS variant:



John taught 20 minutes every Monday.

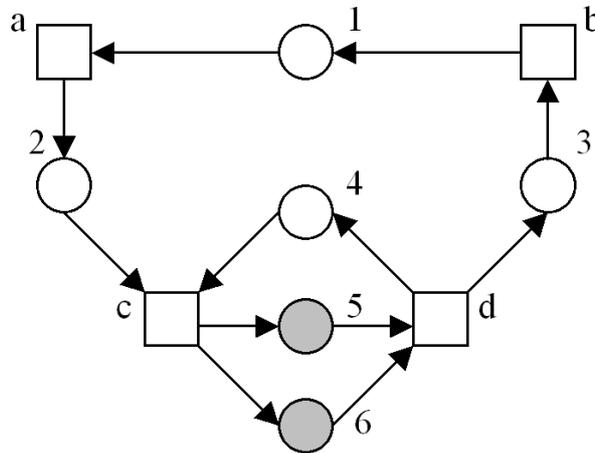


Fig. 4. The Petri net variant

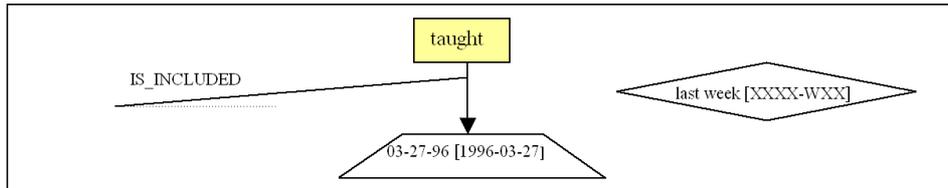
States: 1 — a period from Tuesday to Sunday inclusive; 2 — any period of time on a Monday before teaching; 3 — any period of time on a Monday after teaching; 4 — John is not teaching (this state coincides with the concatenation of states 3, 1 and 2 that make together the complementation to state 5); 5 — a 20 minute period; 6 — John is teaching (highlighted because it is the focus of the temporal situation).

Events: *a* — the moment when a Monday begins; *b* — the moment when a Monday ends; *c* — the moment when John starts teaching; *d* — the moment when John ends teaching.

Due to the use of the universal quantifier *every* the net is represented as a cycle and, unlike the TERQAS variant, shows the relations IS_INCLUDED, HOLDS within its structure, without the need of naming them.

Example 3.

The TERQAS variant:



John taught last week.

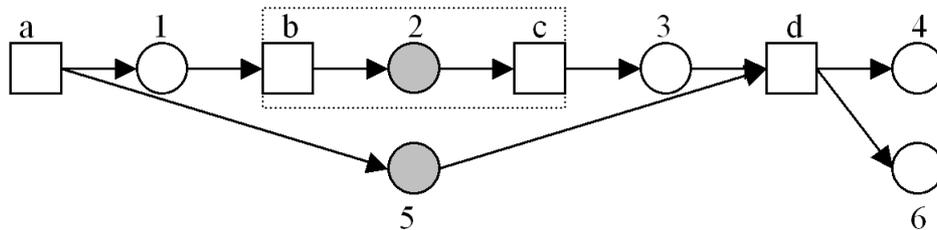


Fig. 5. The Petri net variant

States: 1 — the time before John's teaching last week; 2 — John is teaching; 3 — the time after John's teaching last week; 4 — this week; 5 — last week; 6 — the state of speech.

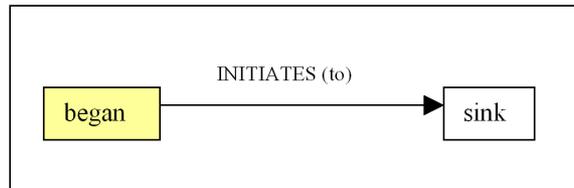
Events: *a* — the beginning of the last week; *b* — the beginning of teaching; *c* — the end of teaching; *d* — the end of last week.

Events *b* and *c* together with state 2 present a process but can be seen as a single event due to coercion, see also explanation to example 5.

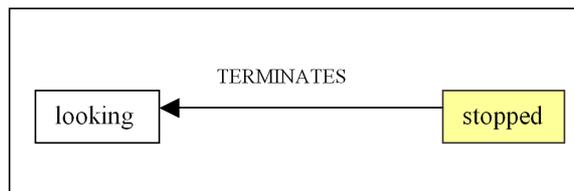
As for the examples with the events classified as ASPECTUAL, Petri nets are very similar to the schemes in [Pustejovsky 2002, p. 40] with such a difference that they preserve the time flow direction and the Event-State distinction. They also clearly show the purely functional status of the ASPECTUALS.

Example 4.

The TERQAS variant:



The boat began to sink.



The search party stopped looking for the survivors.

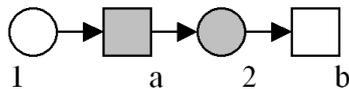


Fig. 6. The Petri net variant

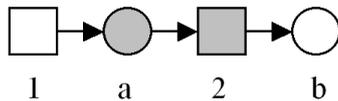


Fig. 7. The Petri net variant

The highlighted squares here correspond to the beginning and to the end of a State respectively. It might be worth mentioning that some languages tend to include ASPECTUAL meanings (another term for them is 'phase' verbs) into the lexical meaning of verbs. For instance, Slavonic languages have developed special Aktionsarten (lexical aspects) of such verbs. That would be an argument for trying to conceptualize the semantic structure of a situation rather than explicit lexical items. If we needed to contrast two languages with different ways of expressing phase relations we would need to find a common metalanguage for that, which is what Petri nets seem to be.

The examples above show that it is worth while keeping the differentiation between states and events (in Petri understanding) as well as temporal relations involving them. Such a differentiation is essential for a unified formal presentation of temporality.

Example 5.

This example is somewhat more complicated and might seem slightly unnatural. The sentence is taken from [Moens & Steedman 1988, p. 21]¹⁰, where it was meant to demonstrate the phenomenon of lexical aspectual coercion. We present it also to show how Petri nets can deal with representing time frequency relations.

It took me two days [to learn] to play the ‘Minute Waltz’ in less than sixty seconds for more than an hour.

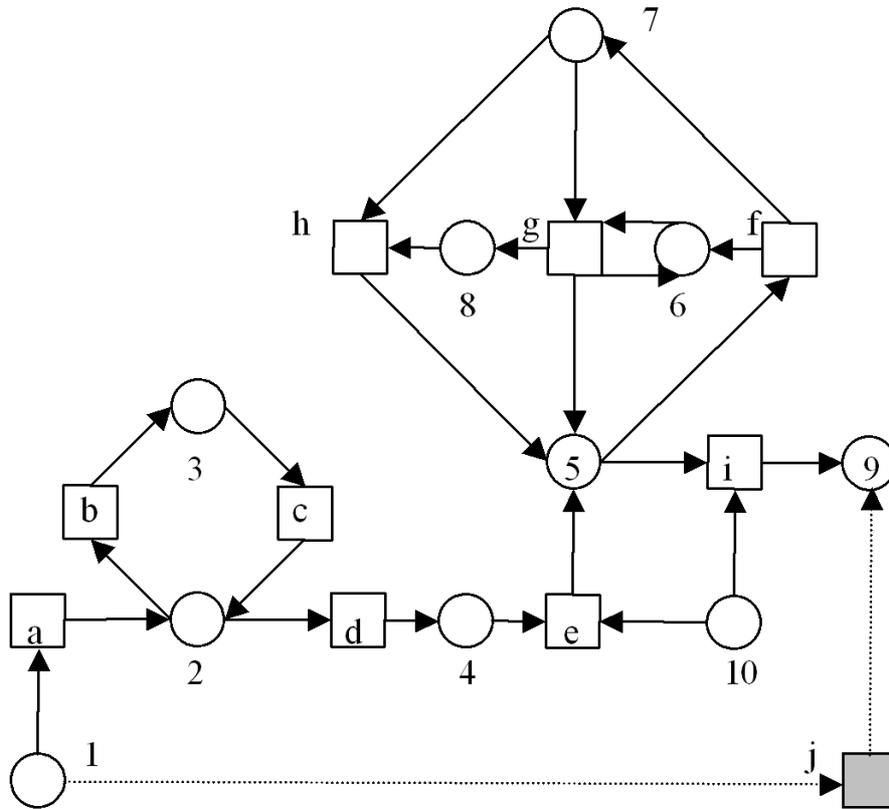


Fig. 8. Petri net representation

We understand that the sentence describes a process of learning which consists of two steps: 1. learning/training to play ‘Minute Waltz’ in less than 60 seconds (cycle 2-b-3-c) and 2. learning/training to be able to keep playing with this tempo for more than an hour (cycles 5-f-6-g-7-h-5 and 5-f-8-h).

States: 1 — cannot play the ‘Minute Waltz’ in less than 60 seconds; 2 — playing the waltz to train; 3 — not playing; 4 — can play the ‘Minute Waltz’ in less than 60 seconds; 5 — not playing; 6 — playing the waltz within training2 cycle; 7 — one

¹⁰Cited from [Schenner 2005].

hour time; 8 — time in training2 cycle before an hour ends but after playing has been stopped; 9 — can play the ‘Minute Waltz’ in less than 60 seconds for more than a hour; 10 — two days period.

Events: a — begin training1; b — stop playing (waltz finished); c — start playing again; d — stop training1; e — start training2; f — start training2 cycle; g — beginning and end of playing the waltz within the training2 cycle; h — stop training2 cycle; i — stop training2; j — learn to play ‘Minute Waltz’ in less than 60 seconds for more than an hour, conceptualized as a single event.

The graph shows well how the mechanism of coercion works. Event j is a condensed representation of the whole training process structure which can be seen from a further perspective as an achievement in Vendlerian understanding.

Petri nets and representation of discourse

Inclusion of temporal expressions into Petri nets representation can also be a step towards showing more complicated sentence structures and can be extended to **discourse representation** as well.

Comparing TERQAS graphs and Petri nets we can see that the latter ones show a lot of information which is not expressed explicitly. This might seem to be a redundancy *prima facie* but when we try to develop a broader view of a situation, we can see that many of those implicit elements can easily be and often are explicated in neighbouring sentences. If we do not visualize them at the beginning, we need to draw a separate structure for them later, as they appear in the discourse. If we have them at once as ‘silent’ states or events, like it is in Petri nets, we only need to number them in the order they appear.

In this way Petri nets can also serve as **anaphora** resolution mechanism. When juxtaposing two EVENTS with different predicate-argument structures we show them in different parallel chains of states/events that are connected depending on how they are correlated in time. Thus, the agent of a described EVENT is repeated automatically in the successive states/events. Two EVENTS with different agents cannot be placed at the same chain, even if there exists one and the same event which clearly divides the two described states of those agents. The reason for that is that Petri nets need to show explicitly that after a certain event the state holds no more and, vice versa, before a certain event a state did not hold.

Let us show now some examples, comparing at the same time Petri nets with the Dynamic Aspect Trees (DAT) system developed by ter Meulen [1995]¹¹.

DATs are used to show temporal dependencies and are capable of showing that EVENTS took place chronologically even if that was not explicated by lexical or grammatical means. The order of appearing in the discourse is a sufficient indicator for that. Ter Meulen named mnemonically aspectual classes that correlate in time with verbal forms which follow them in the discourse. The aspectual classes differentiated by ter Meulen — *holes*, *filters* and *plugs* — roughly correspond to Moens and Steedman’s (Vendlerian) *activities*, *accomplishments* and *achievements* respectively, according to the observation of Setzer [2001]. However, they can be represented solely by means of Petri states and events or their combinations.

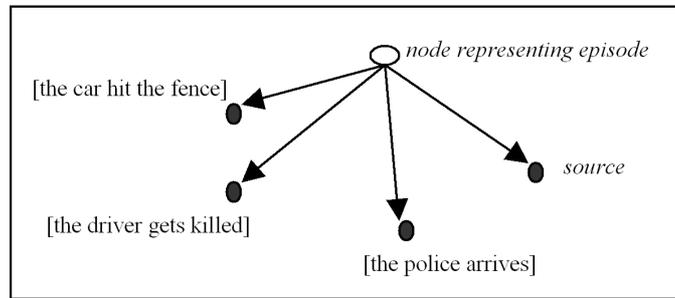
¹¹Cited by [Setzer, 2001].

Below is an example of a sequence of *plugs* which roughly correspond to events in Petri nets: “If a sentence is interpreted as describing a *plug*, information about what happened at the same time is blocked, the temporal focus is redirected and subsequent sentences are interpreted as describing later events” [Setzer 2001, 51].

Let us differentiate between the following two types of sequential representation of events:

1. events share the same agent, e.g. *Jane arrived. She went straight to her room.*
2. events have different agents, e.g. *The car hit the fence. The driver was killed. The police arrived.*

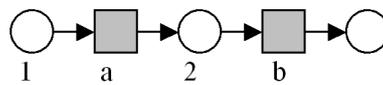
Ter Meulen’s presentation of those two situations will be similar (we show here only the second one):



The chronological order of the events is shown by placing them from left to right, connected by a single situation (the top node). A *source* in DATs corresponds to a state of speech in Petri nets. According to the author it is always the rightmost to show that everything that is reported happened earlier.

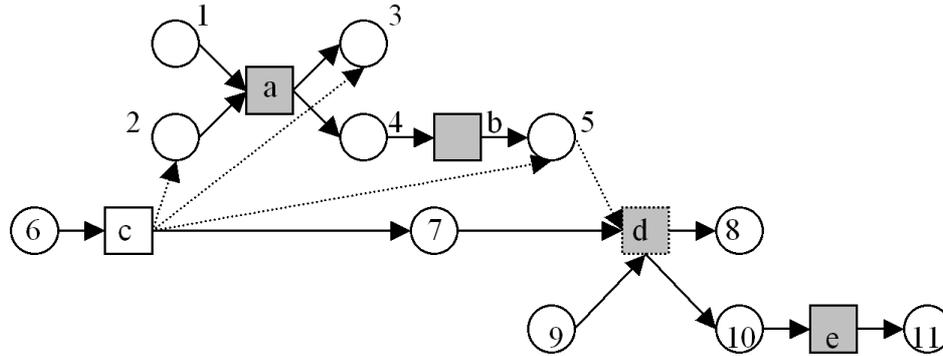
Representation of those two situations in Petri nets will be considerably different. We shall try to show below that this differentiation is significant for anaphora resolution.

1. *Jane arrived. She went straight to her room*



States: 1 — Jane before the arrival; 2 — Jane is here but not yet in her room; 3 — Jane is in her room. Events: a — Jane’s arrival; b — Jane goes to her room.

2. *The car hit the fence. The driver was killed. The police arrived.*



States: 1 — the car before it has hit the fence; 2 — the driver before his car has hit the fence; 3 — the car after it has hit the fence; 4 — the driver after his car has hit the fence; 5 — the driver is dead; 6 — a witness before (s)he notices the situation above, i.e. the state of a person before (s)he becomes a witness of the situation; 7 — being a witness (observing the situation), simultaneous with the accident; 8 — having been a witness of the situation; 9 — the police before they know about the accident; 10 — the police know about the accident and are getting to the place where it has happened; 11 — the police are at the place of the accident.

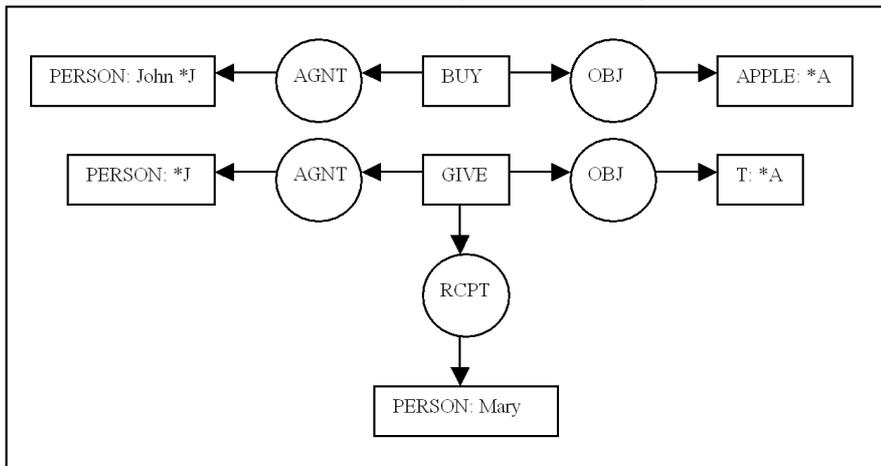
Events: a — the car hits the fence; b — the driver dies; c — somebody notices what is happening to the car and the driver (we do not know at which moment of time the observation began, that is why potential moments are shown by dotted lines); d — the witness informs the police; e — the police arrive.

The events and states related to different agents are presented in parallel chains which nevertheless can share some of the events (in our case these are a and d) when those agents are the arguments of the same predicate-argument structures (in TimeML such cases are defined as **identical** events). Our Petri graph shows that the event of hitting the fence by the car was the same event that happened to the driver, which changed both his and his car's state. The change of state for the driver led to the event of his death. The police must have learnt about what had happened, otherwise there would be no logical connection between the described earlier actions and the fact of their arrival, which is indispensable for discourse coherence. The event of being informed (we need to consider the fact that there had to be somebody who learnt about what had happened and informed the police) made the police come to the place of the accident. We can see that it was necessary to add more states and events to show the connections between the verbalized actions. It is normal to omit them in the overt discourse because they can be easily reconstructed by language users. We may consider omitting them as well in a simplified version of a net. However, should we later have a sentence like *The witness of the accident who had informed the police was still there*, we would not need to add the state of seeing the accident and the event of informing the police

but only to numerate and highlight those already shown in the net. Gradually, the net presents the whole described situation. The **dynamics** of the discourse is shown by the numeration of the relevant (additionally highlighted) states, events or their combinations.

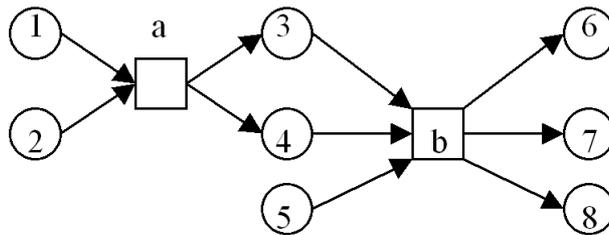
The Conceptual Graph Theory (CG) by Sowa [1984], although “lacks structures for representing verb tenses... provides the means to represent not only complex sentences with relative clauses but also anaphora and indexicals” [Setzer 2001, 54].

Sowa’s Conceptual Graph, taken from [Setzer 2001, 56]:



Above is an example of CG representation of the discourse: *John buys an apple and he gives it to Mary.* and below is its Petri net correspondent.

The Petri net variant:



States: 1, 3, 6 — states of John; 2, 4, 7 — states of the apple; 5, 8 — states of Mary. 1 — John does not have an apple; 2 — John has an apple; 3 — the apple is not owned by John; 4 — the apple is owned by John; 5 — Mary does not have the apple; 6 — John does not have the apple; 7 — the apple is owned by Mary; 8 — Mary owns the apple.

Events: a — John buys an apple; b — John gives the apple to Mary

Unlike in the examples above, this time the Petri net seems to be more concise than the graph we compare it with, which proves that in general Petri nets rep-

resentations are just much more informative than other methods of visualization presented here.

We believe that this example is worth mentioning here due to a higher number of participants of the same events, which cannot be seen in the other examples of this paper. By differentiating participant lines we can keep anaphoras and their antecedents connected.

As for other ter Meulen’s aspectual classes that create different types of temporal discourse dependencies, *filters* with their quite a broad span of meaning¹² have been illustrated in many Petri nets’ samples earlier in this paper.

Holes are defined as follows: “. . . the starting point of the *hole* must precede the starting point of the next event. But the next event can go on longer than the hole” [Setzer 2001, 51].

They have been presented in some of the examples of [Koseska-Toszewa, Mazurkiewicz 2004] and [Koseska-Toszewa et al., 1996] which show that we are not necessarily able to synchronize two or more simultaneous time flows all of the time if the agents involved into them have parted and are located in different places. But certain events involving both or all of the agents that might happen later may bring the time flows together again.

Petri nets, unlike other known to us ways of graphic representation of meanings of natural language sentences, show more than we say but just about enough of what we think when we describe a situation. We believe it is only a seeming redundancy — by showing the whole structure of a situation we have the common basis for different ways of conceptualizing it in one and the same language, as well as in different languages, which is especially significant for contrastive grammar studies.

Abstract

An attempt to extend the use of Petri nets to represent adverbial as well as verbal temporal expressions for elucidating NL sentences’ meanings has been made. A classification of temporal relations and their graphic representation by means of Petri nets has been proposed. We compare the ways events and times are conceptualized in the Petri nets tradition and other existing visualization schemes for temporal relations. There has also been given an outline of how the nets could be applied for the discourse representation.

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¹² “. . . they create a choice for the next sentence to be interpreted as either describing a later event, or an event temporally included in the *filter*, or happening simultaneously. . .” [Setzer 2001, 51].

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Natalia Kotsyba

WYRAŻANIA ZNACZEŃ TEMPORALNYCH ZA POMOCĄ SIECI PETRI’EGO

Streszczenie

W artykule przeprowadzona została próba przedstawienia znaczeń przysłówkowych jednostek temporalnych za pomocą sieci Petriego jako rozszerzenie już istniejącego aparatu prezentacji form modalno-temporalnych. Została zaproponowana klasyfikacja relacji temporalnych oraz ich prezentacja graficzna. Porównano sposoby konceptualizacji zdarzeń i wyrażeń temporalnych za pomocą sieci Petriego z innymi istniejącymi metodami wizualizacji znaczeń temporalnych czasownikowych i nieczasownikowych. Przedstawiony został także krótki zarys możliwości stosowania sieci do reprezentacji dyskursu.