

A METAONTOLOGY FOR MEDICAL DIAGNOSTICS OF ACUTE DISEASES. PART 3. A FORMAL DESCRIPTION OF THE CAUSES OF SIGNS' VALUES AND OF DISEASES

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Abstract: *This article is the final part of the formal description of the metaontology for medical diagnostics in the language of applied logic. It contains a description of the causes of signs' values and of the causes of diseases.*

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Introduction

This article is the continuation of [1] and [2] where the formal definitions of the basic terms of the metaontology and the terms of knowledge and situations that describe the cause-and-effect relations were given. In this article the terms which describe the causes of values of signs during intervals of their development, and also the causes of diseases from the diagnosis are presented.

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1. The terms and agreements which describe development intervals of a sign

In this section the relationships are presented which specify the cause-and-effect relations which act during an interval of the partition of the time axes corresponded to a sign. These relationships determine the values of this sign and also the bounds of the partition.

1.1. A description of the causes of the values of a sign during an interval of its development and their properties

In this section the relationships are presented that specify which from the cause-and-effect relations that act during a time interval associated with an examined sign determine the values of this sign. For this purpose the set of all the possible cause-and-effect regularities which can regulate the values of the considered sign at all the time moments belonging to this interval is defined. A concept of the priority of a cause of the values of a sign is introduced. The priority depends on the modality of a cause-and-effect relation («necessity» has higher priority than «possibility») and on the class to which the relation belongs (the order of priority's increasing is the following: a normal reaction << a response to an event's influence << a clinical manifestation << a clinical manifestation modified by an event's influence << a clinical manifestation of a disease-complication << a clinical manifestation of a disease-complication modified by an event's influence). The cause-and-effect relation which determines the values of the sign during this development interval has the maximal priority for the set of possible causes.

1.1.1. "Possible causes for values of sign" is a function that takes a development interval of a sign and returns the set of all such cause-and-effect relations (normal reactions, responses to event's influence, clinical manifestations and clinical manifestations modified by event's influence) from the situation which proceed during the whole

development interval of the sign and thus, can determine the values of this sign during this interval (moreover, if a cause-and-effect relation is a clinical manifestation or a clinical manifestation modified by event's influence then the disease proceeds during the whole development interval of the sign).

possible causes for values of sign $\equiv (\lambda$ (development interval of sign: development intervals of sign)
 $\{(normal\ reaction: normal\ reactions)\ effect(normal\ reaction)=sign(development\ interval\ of\ sign)\} \cup$
 $\cup \{(response\ to\ event's\ influence: responses\ to\ event's\ influence)$
 $effect(response\ to\ event's\ influence) = sign(development\ interval\ of\ sign) \&$
 $\& interval(development(sign(development\ interval\ of\ sign)), number\ of\ interval(development\ interval\ of\ sign))$
 $\subseteq I[element(dynamics\ of\ values(variant(response\ to\ event's\ influence)),0),$
 $element(dynamics\ of\ values(variant(response\ to\ event's\ influence)),$
 $length(dynamics\ of\ values(response\ to\ event's\ influence))]\} \cup$
 $\cup \{(cause-and-effect\ relation: clinical\ manifestations \cup clinical\ manifestations\ modified\ by\ event's\ influence)$
 $effect(cause-and-effect\ relation) = sign(development\ interval\ of\ sign) \&$
 $\& interval(development(sign(development\ interval\ of\ sign)), number\ of\ interval(development\ interval\ of\ sign)) \subseteq$
 $\subseteq I[element(dynamics\ of\ values(variant(cause-and-effect\ relation)),0),$
 $element(dynamics\ of\ values(variant(cause-and-effect\ relation)), length(dynamics\ of\ values(cause-and-effect$
 $relation))]\} \& interval(development(sign(development\ interval\ of\ sign)), number\ of\ interval(development$
 $interval\ of\ sign)) \subseteq I[element(development(cause(cause-and-effect\ relation)), 0), element(development($
 $cause(cause-and-effect\ relation)), length(development(cause(cause-and-effect\ relation))]\}$

1.1.2. "Priority of values of sign" is a predicate of two variables. It takes two possible causes which can determine the values of signs during their development intervals and returns truth if and only if the both causes relate to the same sign and to the same development interval of this sign and the first cause is more priority than the second one, that is one of the following takes place:

a) the cause-and-effect relation corresponding to the value of the first argument is a response to event's influence with modality of *necessity* and the cause-and-effect relation corresponding to the value of the second argument is one of the following:

- a normal reaction,
- a response to event's influence with the modality of *possibility*;

b) the cause-and-effect relation corresponding to the value of the first argument is a clinical manifestation of a disease from the diagnosis with the modality of *necessity* and the cause-and-effect relation corresponding to the value of the second argument is one of the following:

- a normal reaction,
- a response to event's influence,
- a clinical manifestation of a disease from the diagnosis with the modality of *possibility*;

c) the cause-and-effect relation corresponding to the value of the first argument is a clinical manifestation of a disease from the diagnosis modified by an event's influence with the modality of *necessity* and the cause-and-effect relation corresponding to the value of the second argument is one of the following:

- a normal reaction,
- a response to event's influence,
- a clinical manifestation of a disease from the diagnosis,
- a clinical manifestation of a disease from the diagnosis modified by an event's influence with the modality of *possibility*;

d) the cause-and-effect relation corresponding to the value of the first argument is a clinical manifestation of a disease from the diagnosis (possibly modified by an event's influence), and this disease is a complication (possibly indirect) of another disease, its modality is *necessity*, and the cause-and-effect relation corresponding to the value of the second argument is one of the following:

- a clinical manifestation of the second disease,
 - a clinical manifestation of the second disease modified by an event's influence.
- priority of values of sign $\equiv (\lambda(\text{CER1: cause-and-effect relations}) (\text{CER2: cause-and-effect relations})$
 $(\vee (\text{development interval of sign: } \textit{development intervals of sign})$
 $\text{CER1} \in \textit{possible causes for values of sign} (\text{development interval of sign}) \&$
 $\& \text{CER2} \in \textit{possible causes for values of sign} (\text{development interval of sign}) \&$
 $\& ((\text{CER1} \in \textit{responses to event's influence} \& \textit{modality}(\text{CER1}) = \textit{necessity} \&$
 $\& (\text{CER2} \in \textit{normal reactions} \vee \text{CER2} \in \textit{responses to event's influence} \& \textit{modality}(\text{CER2}) = \textit{possibility})) \vee$
 $\vee (\text{CER1} \in \textit{clinical manifestations} \& \textit{modality}(\text{CER1}) = \textit{necessity} \&$
 $\& (\text{CER2} \in \textit{normal reactions} \cup \textit{responses to event's influence} \vee \text{CER2} \in \textit{clinical manifestations} \&$
 $\& \textit{modality}(\text{CER2}) = \textit{possibility})) \vee (\text{CER1} \in \textit{clinical manifestations modified by event's influence} \&$
 $\& \textit{modality}(\text{CER1}) = \textit{necessity} \& (\text{CER2} \in \textit{normal reactions} \cup \textit{responses to event's influence} \cup \textit{clinical}$
 $\textit{manifestations} \vee \text{CER2} \in \textit{clinical manifestations modified by event's influence} \& \textit{modality}(\text{CER2}) = \textit{possibility})) \vee$
 $\vee (\text{CER1} \in \textit{clinical manifestations} \cup \textit{clinical manifestations modified by event's influence} \& \textit{modality}(\text{CER1}) =$
 $= \textit{necessity} \& (\vee ((\textit{another disease: } \textit{diagnosis}) \textit{connection}(\textit{another disease, } \textit{cause}(\text{CER1}) \&$
 $\& (\text{CER2} \in \textit{clinical manifestations} \cup \textit{clinical manifestations modified by event's influence} \& \textit{cause}(\text{CER2}) =$
 $= \textit{another disease})))))))$

1.1.3. "Causes for values of sign with maximum priority" is a function which takes a sign's development interval and returns only those cause-and-effect relations from the set of *possible causes for values of sign* which have the maximum priority.

causes for values of sign with maximum priority \equiv
 $\equiv (\lambda (\text{development interval of sign: } \textit{development intervals of sign})$
 $\textit{possible causes for values of sign}(\text{development interval of sign}) \setminus$
 $\setminus \{(\text{CER1: } \textit{possible causes for values of sign}(\text{development interval of sign}))$
 $(\vee (\text{CER2: } \textit{possible causes for values of sign}(\text{development interval of sign}))$
 $\textit{priority of values of sign}(\text{CER2, CER1}))\}$)

1.1.4. "Cause of values of sign" is a function that takes a development interval of a sign and returns the cause-and-effect relation that takes place in the situation (a normal reaction; a response to the event's influence that happened at a moment; a clinical manifestation of a disease from the diagnosis during some its development period; a clinical manifestation of a disease from the diagnosis modified by event's influence that happened at a moment) and determines the values of this sign during this development interval.

sort cause of values of sign: $\textit{development intervals of sign} \rightarrow \textit{cause-and-effect relations}$

1.1.5. The cause of the values of a sign which were obtained during a development interval of this sign has the maximum priority.

$(\text{development interval of sign: } \textit{development intervals of sign})$
 $\textit{cause of values of sign}(\text{development interval of a sign}) \in$
 $\in \textit{causes for values of sign with maximum priority}(\text{development interval of a sign})$

1.1.6. If the cause of the values of a sign which were obtained during a development interval of this sign is a normal reaction then any value of this sign examined at any moment during this interval belongs to the range of the effect for a variant of this normal reaction.

$(\text{development interval of sign: } \textit{development intervals of sign})$
 $(\text{moment of examination: } \textit{moments}(\textit{sign}(\text{development interval of sign})) \cap$
 $\cap \textit{interval}(\textit{development}(\textit{sign}(\text{development interval of sign}))),$
 $\textit{number of interval}(\text{development interval of sign}))$

cause of values of sign(development interval of sign) \in normal reactions \Rightarrow

\Rightarrow sign(development interval of sign)(moment of examination) \in

\in range of effect(variant(cause of values of sign(development interval of sign)))

1.1.7. If the cause that determines the values of a sign which were obtained during a development interval of this sign is a cause-and-effect relation of one of the following types:

- a response to event's influence;
- a clinical manifestation;
- a clinical manifestation modified by event's influence

then the values of this sign at any moment of the sign's examination that belongs to this development interval of this sign and to a dynamics period of the active variant of this cause-and-effect relation belong to the range of the effect for this dynamics period of this variant of the cause-and-effect relation.

(development interval of sign: {(interval: development intervals of sign) cause of values of sign \in
 \in cause-and-effect relations \ normal reactions })

(dynamics period:

$|[1, \text{number of dynamics periods}(\text{variant}(\text{cause of values of sign}(\text{development interval of sign})))]$)

(moment of examination: $\text{moments}(\text{sign}(\text{development interval of sign})) \cap \text{interval}(\text{development}(\text{sign}(\text{development interval of sign})), \text{interval number}(\text{development interval of sign})) \cap \text{interval}(\text{dynamics of values}(\text{cause of values of sign}(\text{development interval of sign})), \text{moment of examination}))$

$\text{sign}(\text{development interval of sign})(\text{moment of examination}) \in$

\in range of effect(description of dynamics(variant(cause of values of sign(development interval of sign)))
 (dynamics period))

1.2. Properties of a partition of the time axis of a sign

This section contains the conditions for borders of time axis partition intervals related to a sign.

1.2.1. "The same cause-and-effect relation" is a predicate which takes two cause-and-effect relations and returns *true* if and only if their effects are the same and furthermore they both have one of the following types:

- normal reactions;
- responses to event's influence with the same cause-event that happened at the same moment;
- clinical manifestations of the same disease from the diagnosis during the same development interval;
- clinical manifestations of the same disease from the diagnosis modified by the same event that happened at the same moment.

the same cause-and-effect relation \equiv

$\equiv (\lambda (\text{CER1: cause-and-effect relations})$

(CER2: cause-and-effect relations)

(CER1 \in normal reactions & CER2 \in normal reactions \vee

\vee CER1 \in responses to event's influence & CER2 \in responses to event's influence &
 & reason-event(CER1) = reason-event(CER2) &

& element(dynamics(CER1), 0) = element(dynamics(CER2), 0) \vee

\vee CER1 \in clinical manifestations & CER2 \in clinical manifestations &
 & cause(CER1) = cause(CER2) &

& development period of disease(CER1) = development period of disease (CER2) \vee

\vee CER1 \in clinical manifestations modified be event's influence &

& CER2 \in clinical manifestations modified be event's influence &

& cause(CER1) = cause(CER2) & cause-event(CER1) = cause-event(CER2) &

$\& \text{element}(\text{dynamics}(\text{CER1}), 0) = \text{element}(\text{dynamics}(\text{CER2}), 0) \& \text{effect}(\text{CER1}) = \text{effect}(\text{CER2})$

1.2.2. If the values of a sign are determined by the same cause-and-effect relation during two development intervals of this sign then they are determined by the same variant of this relation.

(interval 1: *development intervals of sign*)

(interval 2: *development intervals of sign*)

$\text{sign}(\text{interval 1}) = \text{sign}(\text{interval 2}) \&$

$\& \text{the same cause-end-effect relation}(\text{cause of values of sign}(\text{interval 1}), \text{cause of values of sign}(\text{interval 2})) \Rightarrow$

$\Rightarrow \text{variant}(\text{cause of values of sign}(\text{interval 1})) = \text{variant}(\text{cause of values of sign}(\text{interval 2}))$

1.2.3. "*Adjacent development intervals of sign*" is a predicate that takes two development intervals of a sign and returns *true* if and only if the sign has no less than two development intervals and the first interval precedes the second.

adjacent development intervals of sign \equiv

$\equiv (\lambda (\text{interval 1: } \textit{development intervals of sign})(\text{interval 2: } \textit{development intervals of sign})$

$\text{sign}(\text{interval 1}) = \text{sign}(\text{interval 2}) \& \text{number of an interval}(\text{interval 2}) - \text{number of an interval}(\text{interval 1}) = 1)$

1.2.4. The causes for values of a sign during adjacent development intervals of this sign are different.

(interval 1: *development intervals of sign*) (interval 2: *development intervals of sign*)

adjacent development intervals of sign(interval 1, interval 2) \Rightarrow

$\Rightarrow \text{cause of values of sign}(\text{interval 1}) \neq \text{cause of values of sign}(\text{interval 2})$

1.2.5. If the causes of values of a sign during adjacent development intervals are not normal reactions then the bound between these intervals is either the end of the dynamics of values of the cause-end-effect relation during the first interval or the beginning of the dynamics of values of the cause-end-effect relation during the second interval.

(interval 1: *development intervals of sign*) (interval 2: *development intervals of sign*)

adjacent development intervals of sign(interval 1, interval 2) $\&$

$\& \text{cause of values of sign}(\text{interval 1}) \notin \text{normal reactions} \&$

$\& \text{cause of values of sign}(\text{interval 2}) \notin \text{normal reactions} \Rightarrow$

$\Rightarrow \text{element}(\text{development}(\text{sign}(\text{interval 1})), \text{interval number}(\text{interval 1})) \in$

$\in \{ \text{element}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval 1})),$

$\text{length}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval 1}))),$

$\text{element}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval 2})), 0) \}$

1.2.6. If the reason of values of a sign during one of its development intervals is a normal reaction then the border between this and next interval is the beginning of the dynamics of values for the cause-and-effect relation which is the cause of the values of the sign during the second interval.

(interval 1: *development intervals of sign*) (interval 2: *development intervals of sign*)

adjacent development intervals of sign(interval 1, interval 2) $\&$

$\& \text{cause of values of sign}(\text{interval 1}) \in \text{normal reactions} \Rightarrow$

$\Rightarrow \text{element}(\text{development}(\text{sign}(\text{interval 1})), \text{interval number}(\text{interval 1}))$

$= \text{element}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval 2})), 0)$

1.2.7. If the cause of the values of a sign during one of its development intervals is a normal reaction then the border between this and previous interval is the end of the dynamics of values for the cause-end-effect relation which is the cause of the values of the sign during the first interval.

(interval 1: *development intervals of sign*)

(interval 2: *development intervals of sign*)

adjacent development intervals of sign(interval 1, interval 2) $\&$

$\& \text{cause of values of sign}(\text{interval 2}) \in \text{normal reactions} \Rightarrow$

$$\begin{aligned} &\Rightarrow \text{element}(\text{development}(\text{sign}(\text{interval } 1)), \text{interval number}(\text{interval } 1)) = \\ &= \text{element}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval } 1), \\ &\quad \text{length}(\text{dynamics of values}(\text{cause of values of sign}(\text{interval } 1)))) \end{aligned}$$

2. A description of causes of diseases from diagnosis

In this section the relationships are presented which determine what cause-and-effect relation (from the sets of etiologies and complications) is the real cause of a disease from the diagnosis. For this purpose the set of all possible casual relations is determined which might be the cause of the disease. A concept of priority for disease's cause is introduced. The priority depends on the modality of cause-and-effect relation ("*necessity*" has more priority than "*possibility*") and on the moment when this relation begins to act (the earlier cause has more priority). The cause-and-effect relation which is the cause of the disease has the maximum priority among all the possible causes.

2.1. "*Possible causes of disease*" is a function that takes a disease from the patient's diagnosis and returns the set of all the complications and etiologies from the situation for which the effect is this disease.

$$\begin{aligned} \text{possible causes of a disease} &\equiv \\ &\equiv (\lambda(\text{disease: diagnosis}) \\ &\quad \{ (\text{cause-end-effect relation: complications} \cup \text{etiologies}) \\ &\quad \text{effect}(\text{cause-end-effect relation}) = \text{disease} \}) \end{aligned}$$

2.2. "*Priority of disease's causes*" is a predicate of two variables. It takes two possible causes of a disease and returns *true* if and only if both causes are related to the same disease and the first cause has more priority than the second one that means one of the following:

- the modality of each cause-and-effect relation is *necessity* and the first relation started to act earlier than the second one;
- the modality of the first cause-and-effect relation is *necessity*, the modality of the second one is *possibility* and the first one started to act not later than the second one.

$$\begin{aligned} \text{priority of disease's causes} &\equiv \\ &\equiv (\lambda (\text{CER1: complications} \cup \text{etiologies})(\text{CER2: complications} \cup \text{etiologies}) \\ &\quad (\vee (\text{disease: diagnosis}) \\ &\quad \text{CER1} \in \text{possible causes of disease}(\text{disease}) \& \\ &\quad \& \text{CER2} \in \text{possible causes of disease}(\text{disease}) \& \\ &\quad \& / ((\text{CER1} \in \text{etiologies}) \& (\text{modality}(\text{CER1}) = \text{necessity}) \Rightarrow \text{moment}(\text{CER1}), \\ &\quad ((\text{CER1} \in \text{complications}) \& (\text{modality}(\text{CER1}) = \text{necessity}) \Rightarrow \text{element}(\text{development}(\text{cause}(\text{CER1}), 0))) / < \\ &\quad < / ((\text{CER2} \in \text{etiologies}) \& (\text{modality}(\text{CER2}) = \text{necessity}) \Rightarrow \text{moment}(\text{CER2}), \\ &\quad ((\text{CER2} \in \text{complications}) \& (\text{modality}(\text{CER2}) = \text{necessity}) \Rightarrow \text{element}(\text{development}(\text{cause}(\text{CER2}), 0))) / \vee \\ &\quad \vee / ((\text{CER1} \in \text{etiologies}) \& (\text{modality}(\text{CER1}) = \text{necessity}) \Rightarrow \text{moment}(\text{CER1}), \\ &\quad ((\text{CER1} \in \text{complications}) \& (\text{modality}(\text{CER1}) = \text{necessity}) \Rightarrow \text{element}(\text{development}(\text{cause}(\text{CER1}), 0))) / \leq \\ &\quad \leq / ((\text{CER2} \in \text{etiologies}) \& (\text{modality}(\text{CER2}) = \text{possibility}) \Rightarrow \text{moment}(\text{CER2}), \\ &\quad ((\text{CER2} \in \text{complications}) \& (\text{modality}(\text{CER2}) = \text{possibility}) \Rightarrow \text{element}(\text{development}(\text{cause}(\text{CER2}), 0))) /) \end{aligned}$$

2.3. "*Causes of disease with maximum priority*" is a function that takes a disease from the diagnosis and returns the set of all the causes of this disease which have the maximum priority.

$$\begin{aligned} \text{causes of disease with maximum priority} &\equiv \\ &\equiv (\lambda (\text{disease: diagnosis}) \text{possible causes of disease}(\text{disease}) \\ &\quad \setminus \{ (\text{CER1: possible causes of disease}(\text{disease})) \\ &\quad \quad (\vee (\text{CER2: possible causes of disease}(\text{disease})) \\ &\quad \quad \text{priority of causes of disease}(\text{CER2, CER1})) \}) \end{aligned}$$

2.4. "Cause of disease" is a function that takes a disease from the diagnosis and returns its cause. The cause of a disease can be either an etiology or a complication.

sort *cause of disease*: *diagnosis* \rightarrow *etiologies* \cup *complications*

2.5. The cause of a disease from the diagnosis has the maximum priority.

(*disease*: *diagnosis*) *cause of disease*(*disease*) \in causes of disease with maximum priority(*disease*)

Conclusion

In this article the final part of the metaontology model for medical diagnostics has been presented. This model describes the interrelation of cause-and-effect relations of different types. The metaontology is close to practical concepts of medicine in the Russian Federation and describes the combined and complicated pathology, the dynamics of pathological processes in time and the influence of medical treatment and other events on the manifestation of diseases. The model of metaontology includes the definitions of terms of the knowledge model (parameters), definitions of the terms of the situation model (unknowns), and also a system of relationships that consists of integrity constraints for unknowns and parameters and of relationships between them.

The relationships between unknowns and parameters can be divided into the following groups:

- 1) the relationships between knowledge about cause-and-effect relations and cause-and-effect relations which take place in situations;
- 2) the relationships which determine cause-and-effect relations that are the reasons of values of each sign during its development intervals;
- 3) the relationships which determine the properties of borders of intervals of the time axis for each sign;
- 4) the relationships which determine the reason of each disease from the diagnosis.

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