`TSMI

Buekens, F.A.I.; Ceusters, W.; De Moor, G.; Bernauer, J.; DeKeyser, L.; Surjan, G.

Published in:
International Journal of Medical Informatics

Publication date:
1997

ELSEVIER

International Journal of Medical Informatics 46 (1997) 87–101

International Journal of Medical Informatics

Original article

TSMI: a CEN/TC251 standard for time specific problems in healthcare informatics and telematics

W. Ceusters [a,c], F. Buekens [b], G. DeMoor [c,*], J. Bernauer [d], L. DeKeyser [e], G. Surján [f]

[a] *Office Line Engineering NV, Het Moorhof, Hazenakkerstraat 20, B-9520 Zonnegem, Belgium*
[b] *University of Tilburg, Department of Philosophy, PB 90153, 5000 LE Tilburg, The Netherlands*
[c] *Department of Medical Informatics, University Hospital, De Pintelaan 185, B-9000 Gent, Belgium*
[d] *Institute for Medical Informatics, University of Hildesheim, Samelsonplatz 1, 31141 Hildesheim, Germany*
[e] *Aladin Computing NV, Oeverstraat 7, B-9200 Baasrode, Belgium*
[f] *Haynal University of Health Sciences, Department of Data Service, Budapest, POB 112, Hungary*

Received 1 November 1996; accepted 26 May 1997

Abstract

Time is the most important variable in healthcare, and standards are needed about how to represent information with explicit references to time. In this paper, the European Prestandard 'TSMI: time standards for healthcare specific problems' (CEN/TC251 preENV 12381) is presented which aims to be the first contribution to this harmonisation process, focusing on 'representation' and 'explicit reference' of temporal information in healthcare. The prestandard is mainly composed of two parts. First, the basic building blocks for modelling time-related information are introduced, and a formal representation scheme proposed. In a second part, conformance rules and principles for Healthcare Data and Information as well as for Healthcare Information Systems, are covered. © 1997 Elsevier Science Ireland Ltd.

Keywords: CEN/TC251; Standards; Representation of temporal expressions; Time

1. Introduction

Time is intrinsically connected with medical knowledge and data, while medical temporal reasoning is directly relevant to almost

* Corresponding author. Tel.: +32 9 2403421; fax: +32 9 2403439; e-mail: georges.demoor@rug.ac.be

1386-5056/97/$17.00
PII S1386-5056(97)00050-6

every aspect of medical practice. During history-taking, physicians try to establish the time of onset, duration and chronology of the various symptoms and signs the patient may present or has shown recently, possibly taking into account previous illnesses or concurrent diseases to detect recurrent manifestations. Throughout the diagnostic process, physicians use temporal reasoning strategies in a number of ways. A causal diagnostic explanation, for example, must account for the temporal latency of observed manifestations given the hypothesised etiological factor. Diagnostic decisions are also based on time-dependent constellations of symptoms and signs showing the physician similarities to previous courses or case descriptions in medical textbooks. One particular task in the reasoning process is to represent the temporal information in a structured way such that it is possible to reason from what the patient tells to what events and states must have existed as to the causes and effects of these states. It is the physician's job to describe the inferred cause and effect in an explanatory way [1]. Therapeutic actions and decisions rely heavily on notions such as the patient's past clinical course, current medical status and predicted future course. On the other hand, therapeutical interventions affect the temporal behaviour of manifestations considerably and even may invoke new ones, eventually side effects, leading to an adjustment of the therapeutic plan later on. Patient monitoring also involves analysing the timing of changes in the patient's manifestations. When they are continuously monitored as in an intensive care unit, the exact time when a significant change occurs can be recorded. In other situations, this may not be the case and physicians will have to deal with various types and magnitudes of distortions in subjective time perception, eventually leading to ambiguities in the flow of events.

Various medical information systems exploit temporal information and have developed specialised methods to address the unique storage and retrieval requirements of time-varying clinical data. The adopted approaches, being highly application-dependent, differ in a number of aspects such as the choice of ontological primitives, whether time is viewed as discrete or continuous, the modelling of uncertainty, incompleteness and impreciseness, the granularity of the time stamp chosen, etc. Information exchange between these systems, or integration in large scale healthcare information systems, will only be possible if a high level framework model, rich enough to express the properties of the various approaches in all its aspects, can be developed [2].

Working Group 2 of CEN/TC251 [1], dealing specifically with issues such as terminology, knowledge bases and semantics in healthcare informatics and telematics, recognised the need for the development of such a high level framework model. This led to the formation of Project Team PT2-017 [2] of CEN/TC251 that, covered by the European Commission and the European Free Trade Association, was given the task to prepare a European Prestandard, officialy abbreviated as 'ENV', for a standard representation of time-related expressions in healthcare. The official name of the prestandard is 'Time Standards for Healthcare Specific Problems', with acronym 'TSMI'. The ENV [3] [3] should thus go further

[1] CEN/TC251 is the Technical Committee of the European Commitee for Standardisation (CEN), dealing with Medical Informatics.

[2] CEN/TC251/PT2-017 was composed of an international pluridisciplinar team of experts in the domain of medical informatics, medicine, logic, philosophy and computational linguistics.

[3] TSMI has been accepted by CEN as preENV 12381 since 29/7/96.

than the existing time-standards [4,5] in which only numeric date and time elements were covered.

Section 2 of this paper deals with the scope and limits of the TSMI standard. In Section 3 we present the general framework and the semantic data model of the temporal model. Section 4 presents the levels of semantic specification according to a predefined scheme in which the ranking based on the level of semantic specification reflects different configurations. In Section 5, we assess the applicability of the standard using the existing medical record system called 'MedAr'[4].

2. Purpose, scope and applicability of the TSMI-standard

Preceding studies of the literature carried out by the PT2-017, showed that the future standard should allow, as a minimum requirement, to order temporal facts in three major ways, independent of any specific ontology of time itself:

- by relating situations to a calendar,
- by relating situations to 'reference' situations
- by relating events together in 'before- and after-' chains.

The main reason for this threefold organisation is that our everyday temporal discourse (not necessarily limited to the domain of healthcare) contains a variety of expressions that only with a certain artificiality can be regimented into a uniform style of analysis. Artificiality is an unacceptable feature in man–man communication, but is perfectly acceptable for machine–machine communication, and to a certain extend also for man–machine communication. Hence, it was decided to limit the purpose of the TSMI to enhance, in a perspective of machine–machine and man–machine communication, the generation of statements that are guaranteed to be understood unambiguously with respect to the time-related expressions that are embedded within them.

The purpose of TSMI is not to provide a full-blown temporal logic, replacing what already exists. Also, TSMI does not introduce or force a specific ontology of time, or does it force the use of a fixed representation scheme for such an ontology. However, the proposed standard provides a set of principles for syntactic and semantic representation that allow the comparability of specific ontologies on time, and the exchange of time-related information that is expressed explicitly. As such, TSMI provides a standardised way of representing time-related expressions, such that all kinds of questions about the temporal organisation of events (or whatever similar constructs are called or stand for in specific ontologies) can be answered on the basis of the information available.

It is also not the intention of the proposed standard to provide a means to interpret implicit time-related information. In an expression such as 'diabetes since childhood', 'since childhood' is an explicit temporal reference for the diabetes, but the implicit information—what 'childhood' might mean (e.g. starting at the age of 2 years?)—is not addressed. Interpretation of the source information is the task of the provider of the information itself. Of course, the language provided by TSMI has enough expressive power to allow a specific provider of information to state explicitly what his understanding of 'childhood' is.

In the light of these considerations, the proposed standard is applicable to:

1. developers of medical information systems in which the need is felt to have explicit time-related concepts for internal

[4] MedAr is a trademark of Aladin Computing NV.

organisation (e.g. temporal data bases, temporal reasoning systems),
2. information modellers or knowledge engineers building models for the systems mentioned in (1),
3. experts involved in the development of semantic standards on precise subdomains in health care where time-related information need to be covered, (e.g. in the study of Pathochronology, i.e. the discipline dealing with the time course of specific diseases),
4. developers of interchange formats for messages in which time-related information is embedded.

On the other hand, the proposed standard is not intended to be used directly for representing what is true in time, reasoning about time or the representation of metrological time (which is covered in other standards).

The TSMI is mainly composed of two parts. First, the basic building blocks for modelling time-related information are introduced, and a formal representation scheme proposed. In the second part, conformance rules and principles for Healthcare Data and Information as well as for Healthcare Information Systems, are covered.

3. Modelling information with temporal references

One of the basic ideas of the proposed standard is to represent information with reference to time through a compositional and recursive model. A unit of time related information—in terms of the proposed standard called *predication*—is composed by a description of information which has no explicit relation to time—called *propositional clause*—and a description carrying explicit reference to time—called *temporal reference*. This schema is illustrated by Fig. 1 in the form of a semantic data model. Within that model, rectangular boxes represent the basic building blocks of the model, while round boxes refer to possible alternatives for a given building block. The syntax for descriptions of time related information which corresponds to this model and which is used in the standard and in this paper is given in Fig. 2.

Predications can refer to situations with different temporal aspects: a *situation* can be either continuous or discontinuous in time. A continuous situation is a phenomenon occurring at a particular time point or over a particular time interval. In this respect a *time interval* is a portion of time of which the duration in a given context is considered to be significant and relevant, in contrast to a *time point* for which this does not hold. In terms of the proposed standard a continuous situation is called an *event*, if it is considered to occur at a particular time point. It is called an *episode*, if it is considered to occur over a particular time interval. Whether a situation is to be considered an event or an episode, is a matter of explicit definition by the provider of the information. For instance, the language expression 'kidney transplantation on 19.12.95' may denote an event (the fact that a day has a duration is not considered to be relevant here by the provider of the information). 'Kidney transplantation with duration of 2 h' (by definition) denotes an episode. A discontinuous situation is a phenomenon occurring at several time points or over several time intervals. In terms of the standard a discontinuous situation is called a *time-series*. Time-series can relate to a series of events, e.g. 'taking tablets every morning', or a series of episodes, e.g. 'fever episodes in the period after transplantation'.

Since a single language expression of a situation can reflect several temporal aspects, the proposed standard tries hard to make the particular aspect explicit in the mind. For

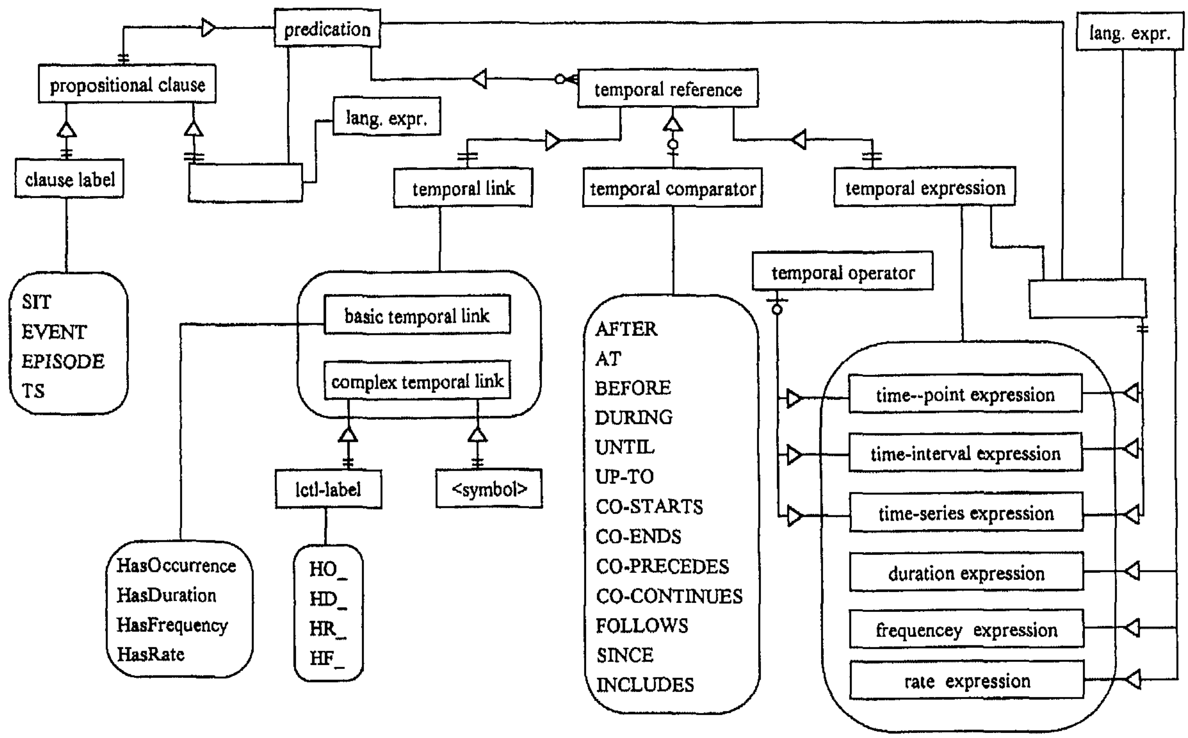

Fig. 1. Semantic data model for descriptions of time related information.

that reason a propositional clause is composed by a language expression—which might refer to a concept of a standardised concept system—and a clause label which is to specify the temporal aspect. Possible clause labels are EVENT, EPISODE, TS (for time-series), or SIT (if the temporal aspect of a situation is insignificant or irrelevant). In the case of a time-series of events or episodes, predications can be nested within a propositional clause, e.g.

EVENT ('transplantation'):	denotes a transplantation under the aspect of an *event* occurring at a particular time-point.
EPISODE ('transplantation'):	denotes a transplantation under the aspect of an *episode* occurring during a particular time-interval.
SIT ('transplantation'):	denotes the *situation* of a transplantation with unspecified temporal aspect.
TS (EVENT ('taking tablets')):	denotes a *time-series* of tablet takings.

A *temporal reference* is the component of a predication which represents time related information. It is composed by a temporal link, a temporal comparator, and a temporal expression. The temporal link captures the semantic relation between the propositional

```
<predication>                  ::=  (<propositional clause>)|
                                    ( <propositional clause> <temporal reference>)
<propositional clause>         ::=  <clause label>(<language expression>) |
                                    <clause label><predication>
<clause label>                 ::=  SIT | EVENT | EPISODE |TS
<temporal reference>           ::=  <temporal reference> <temporal reference> |
                                    (<temp link> [<temp comparator>]
                                     <temp expression>)
<temp link>                    ::=  <basic temp link>| <complex temp link>
<basic temp link>              ::=  HasDuration | HasOccurrence | HasFrequency |
                                    HasRate
<complex temp link>            ::=  <ctl-label> <symbol>
<ctl-label>                    ::=  HO_ | HD_ | HR_ | HF_
<temp comparator>              ::=  AFTER | AT | BEFORE | DURING | UNTIL |
                                    UP-TO | CO-STARTS | CO-ENDS |
                                    CO-PRECEDES | CO_CONTINUES | FOLLOWS |
                                     SINCE | INCLUDES
<temp expression>              ::=  <time-point expression> |
                                    <time-interval expression> |
                                    <time-series expression> | <duration expression> |
                                    <frequency expression> | <rate expression>
<time-point expression>        ::=  <language expression> |
                                    <predication> |
                                    <temporal operator>(<temp expression>)
<time-interval expression>     ::=  <language expression> |
                                    <predication> |
                                    <temporal operator> (<temp expression>)
<time-series expression>       ::=  <language expression> |
                                    <predication> |
                                    <temporal operator> (<temp expression>)
<duration expression>          ::=  <language expression>
<frequency expression>         ::=  <language expression>
<rate expression>              ::=  <language expression>
<temporal operator>            ::=  <symbol>
```

Fig. 2. Syntax for descriptions of time related information (BNF-notation).

clause and the temporal expression. The temporal comparator is the description of a temporal relation and specifies the temporal link. The temporal expression is a description of a time related property. In a predication a propositional clause can be without or combined with one or more temporal references.

A *temporal expression* is either a time-point expression, a time-interval expression, a time-series expression, a duration expression, a frequency expression, or a rate expression. The meaning of these expression types is self-explanatory. Each temporal expression type can be represented by a language expression. The structure of those language expressions is outside the scope of the proposed standard, although if applicable the reference to standard representations of dates and time is preferred. In addition time-point expressions, time-interval expressions and time-series expressions can be represented by a predication. This recursion enhances the expressiveness of the model significantly, since it allows for nesting temporal references. Examples are given at a later stage.

A *temporal link* is either a basic temporal link or a complex temporal link. A *basic temporal link* represents a simple semantic relation. Possible basic temporal links are HasOccurrence, HasDuration, HasFrequency, and HasRate. As the names say these temporal links specify propositional clauses with respect to occurrence, duration, frequency, and rate. In a predication the combination of temporal references with propositional clauses is constrained. Only certain types of temporal links with the appropriate temporal expression types are permitted depending on the particular situation type described by the propositional clause. The possible combinations are listed in Table 1.

A *complex temporal link* is an expression denoting both a semantic relation and a situation. The semantic relation underlying a complex temporal link is one of the basic temporal links. Complex temporal links are covered by the proposed TSMI standard, because they are very important for semantic data modelling in medicine and commonly implemented within medical information systems. Examples of complex temporal links are DateOfBirth for representing the time at which the birth of a person occurred, TimeOfSampleCollection resp. TimeOfSampleAnalysis for representing the occurrence of the collection resp. the analysis of a sample, or HeartRate for representing the frequency of the beating heart of a person. The TSMI standard proposes to make the basic temporal link underlying a complex temporal link explicit within the name. Therefore, the name of a complex temporal link is composed by a label (complex temporal link label), which serves as mnemonic abbreviation for the implied basic temporal link, and a name for the meaning of the link. Examples are:

HO –DateOf-Birth:	is a complex temporal link for assigning a person's birthday.
HF – HeartRate :	is a complex temporal link for assigning a person's heart rate.

Table 1
Allowed combinations of situations, temporal links and temporal expressions in TSMI

Situation	Temporal link	Temporal expression
Event	Has-occurrence	Time point expression
		Time interval expression
		Time-series expression
	Has-frequency	Frequency expression
Episode	Has-occurrence	Time point expression
		Time interval expression
		Time-series expression
	Has-frequency	Frequency expression
	Has-duration	Duration expression
	Has-rate	Rate expression

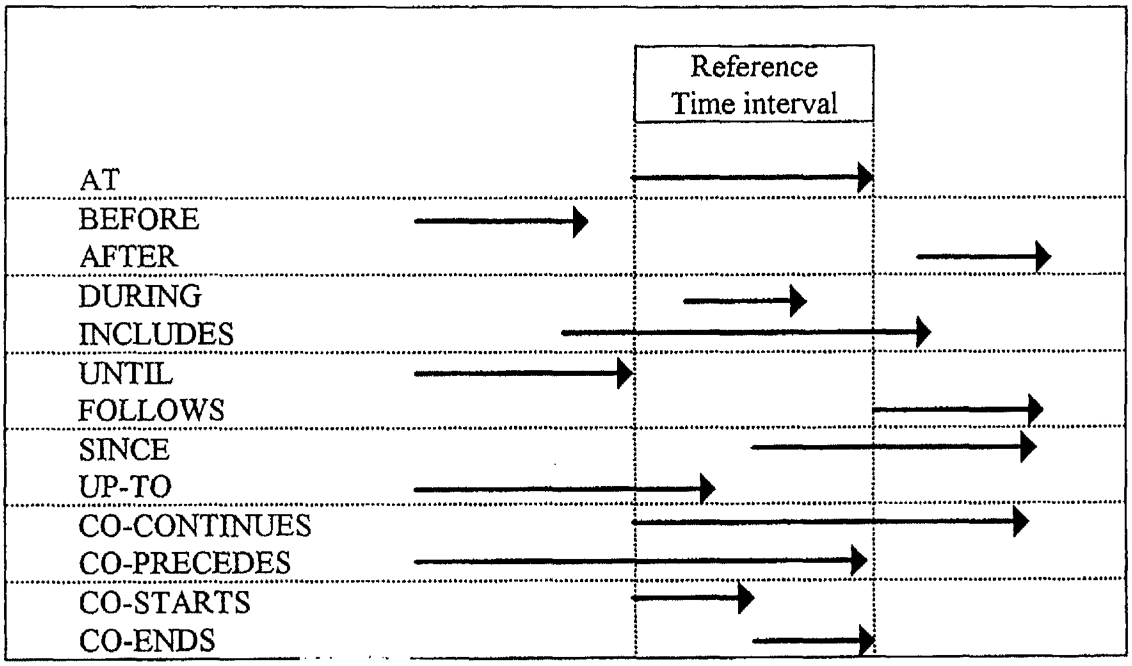

Fig. 3. Semantics of the allowed set of temporal comparators when an episode is temporally related to a time-interval.

Those complex temporal links can also be used to integrate temporal databases where notions such as 'transaction time' are used, e.g. HO_TransactionTime.

A *temporal comparator* is a description of a temporal relation and is to specify the temporal link *HasOccurrence*. The possible temporal comparators AT, BEFORE, AFTER,··· correspond with Allen's time interval relations [6,7]. The semantics of the various temporal comparators for the case of an episode with respect to a time interval is illustrated by Fig. 3. Fig. 4 summarises the permitted combinations in case the reference is to a time-point.

A *temporal operator* is a potential component of a temporal expression and serves as temporal selector. The application of temporal operators is relevant particularly for time-interval expressions and time-series expressions. Examples of temporal operators are *StartMoment* to select the time-point at which a time-interval begins, or *FirstElement* to select the first element of a time-series. It is not within the scope of the proposed TSMI standard to define a complete set of potential temporal operators.

Examples:

StartMoment(EPISODE('transplantation')):	specifies the beginning of a transplantation.
FollowingPeriod(EPISODE('transplantation')):	specifies the period following a transplantation.

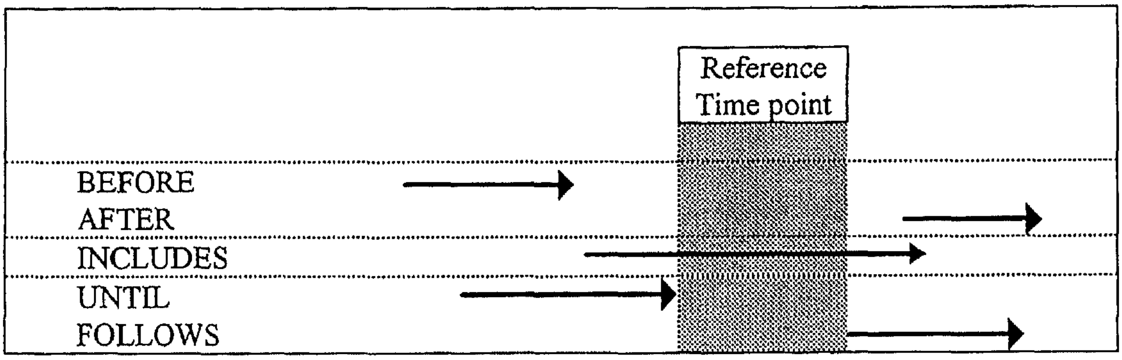

Fig. 4. Semantics of the allowed set of temporal comparators when an episode is temporally related to a time-point.

FirstElement(TS(EPISODE('fever'))):	selects from a seriesof fever episodes the first one.

Finally, the following examples show how the model of the TSMI standard applies to (sometimes very complex) descriptions with explicit reference to time:

Transplantation occurring at 19.12.95:
(EVENT ('transplantation')
(HasOccurence AT ('19.12.95')))

Rejection after transplantation:
(EVENT ('rejection')
(HasOccurrence
AFTER(EVENT('transplantation'))
×))

Rejection within the period after transplantation:
(EVENT ('rejection')
(HasOccurrence
DURING(FollowingPeriod(
EPISODE('transplantation')))))

Rejection which occurs 2 weeks after transplantation:
(EVENT ('rejection')
HasOccurrenceAT
(EndMoment(FollowingPeriod(
EPISODE('transplantation'))
(HasDuration('2 weeks')))))))

Taking of 3 tablets a day until next week:
(EPISODE(
EVENT('take tablets')
(HasFrequency ('3times a day')))
(HasOccurrence UNTIL
(EPISODE ('next week')))

Taking of 2 tablets after every breakfast:
(EVENT ('take 2 tablets')
(HasOccurrence AFTER
(TS(EPISODE('breakfast')))))

Taking of 2 tablets after every breakfast for 1 week.
(EPISODE(
EVENT ('take 2 tablets')
(HasOccurrenceAFTER
(TS(EPISODE('breakfast')))))
(HasDuration ('1 week')))

A series of taking 2 tablets after every breakfast for 1 week before a diagnostic procedure:

```
(TS(
  EPISODE(
    EVENT('take 2 tablets')
      (HasOccurrence AFTER(T-
      S(EPISODE('breakfast')))))
        (HasDuration ('1 week')))
          (HasOccurrenceBEFORE
          (EVENT('diagnostic proce-
          dure')))
```

It is to be noted that the representation of uncertainty with respect to time-related information is deliberately not explicitly covered by this ontology. It is the view of the authors that uncertainty should be dealt with at another level of abstraction, and that mechanisms for representing uncertainty with respect to temporal information should not be different from those related to other types of information.

4. Principles for TSMI conformance

The proposed standard allows developers of healthcare information systems (HIS) to specify to what degree their system can produce or accept information formatted into the elements presented above. Conformance should be specified for each subsystem of the HIS (e.g. medication, clinical history,···), according to the provisions described hereafter. Similarly, information and data (available in data bases, concept systems, etc···) may also be labelled according to the conformance specifications of the TSMI. It is however obvious that for useful exchange of data between different healthcare information systems TSMI is not the only requirement. There is a need for a common domain ontology as well, especially when refering to the concepts behind the language expressions used in the predicates.

TSMI requires that for each system for which conformance with the proposed standard is claimed, the following characteristics shall be described:

LSS	level of semantic specification	specifies to what extent the information related to time is distinguished from the rest of the information.
LRE	level of recursive embedding of time-related information	specifies whether or not the *propositional clauses* are further parsed up to the level of propositional clause zero (clauses not containing new predictions).
LDR	level of deictic referential complexity	specifies characteristics related to the use of *deictic temporal expressions* (i.e. expressions related to the time the expression is used such as 'now', 'yesterday', etc.).
LRC	level of relative referential complexity	specifies characteristics related to the use of *relative temporal expressions.*

LQI	level of formal rigour of *temporal expressions*	specifies to what extent *temporal expressions* can be interpreted by a machine.

Each characteristic is to be labelled according to a predefined scheme in which a higher ranking reflects a more desirable configuration.

4.1. LSS: level of semantic specification

LSS(0): There is no explicit representation of time-related information, nor identification of individual components of the data- or information-model with respect to the basic entities of the standard (*propositional clause*, *temporal reference*, etc).

LSS(1): There is a clear distinction (at the level of allowed recursive embedding) between all the *propositional clauses* and *temporal references* in the subsystem under scrutiny.

LSS(2): (1) There is a clear separation between all the *propositional clauses* and *temporal references* at the allowed level of recursive embedding, and the *temporal links* (*basic* or *complex* ones), and additional *temporal comparators* are clearly identified.
(2) The system need not be able to deal with all the *temporal links* or *temporal comparators* presented in the standard. However, a list of the elements that can be handled, shall be provided.

(3) The restrictions in the combination of *situations*, *temporal links*, *temporal comparators* and *temporal expressions* shall be applied. *Ambiguous temporal expressions* shall be excluded.

LSS(3): In addition to LSS(2), all *temporal links* and comparators can be handled, including the definition of *complex temporal links*.

4.2. LRE: level of recursive embedding of time-related information

LRE(0): The system does not allow for a recursive representation of *propositional clauses* for information related to time.

LRE(1): The system does allow a recursive representation of *propositional clauses* for information related to time. There is however no guarantee that indeed all the *propositional clauses* are brought back down to the level of *propositional clause zero* (i.e. where the propositional clause at the deepest level of the representation does not contain a new predication).

LRE(2): The system allows a recursive representation of *propositional clauses* with respect to information related to time and all the *propositional clauses* (at the deepest level of recursion) are analysed to *propositional clause zero*.

4.3. LDR: level of deictic referential complexity

LDR(0): There are *deictic temporal expressions* in the system[5].

LDR(1): There are no *deictic temporal expressions* in the system.

4.4. LDR: level of relative referential complexity

LRC(0): The system does not allow *relative temporal expressions* to be analysed to the deepest level of reference, or it does not allow *relative temporal expressions* at all.

LRC(1): The system does not allow *relative temporal expressions* to be analysed to the deepest level of reference.

LRC(2): In the system, all *relative temporal expressions* may be analysed to the level of absolute temporal expressions.

4.5. LQI: level of formal rigour of temporal expressions

LQI(0): There is no pre-defined internal structuring of *temporal expressions.*

LQI(1): The internal structure of *temporal expressions* is organised according to a specified syntax.

LQI(2): In addition to LQI(1), all *absolute temporal expressions* are expressed quantitatively following the regulations of ISO 8601: 1988 and ISO 311: 1992 [3,4].

[5] The presence of deictic references is considered to be bad practice, and hence receives a lower quote.

5. TSMI and electronic medical record systems

In order to assess the applicability of the standard prior to final release, an existing electronic medical record system (medAr) has been used as a testbed. MedAr is a medical record application generator running on networked PC's. It is popular with general practitioners as well as with specialists in private and hospital practice. Among clinicians it is renown for its rich representation of clinical data. Despite its relative 'deep' (in contrast with 'superficial') representational structure its representation of time is ontologically still rather primitive. We will not dwell on albeit interesting psycho-economic explanations for this fact. It is suffice to say that clinicians are mostly unaware of the richness of the temporal expressions in which daily medical discourse is immersed.

In hindsight, the temporal aspect of the meta-model of medAr consists of: (i) two levels of discourse (the time of utterance in the computer system and the period of 'validity' of each utterance); (ii) three classes of temporal entities (the patient's life time, the 'things' done unto a patient such as observations (for example: medical tests, physical examination,...), interpretations (for example: diagnosis, medical history,...) plans and acts); and (iii) the contact (grouping the 'things' done unto a patient according to the chronology of the thoughts of origin). For example, strict chronologically, the result of a gastroscopical examination will be available only some time after the consultation during which the order for this examination resulted from the clinicians hypothetico-deductive (diagnostic-therapeutic) cycle. Medical logic would however rather 'sort' the result of the examination within the 'causal' context of the consultation.

To assess the expressive power of the proposed language in the TSMI, the medAr programmers were asked to develop a module able to represent the time-related information in the medical record according to the proposed standard. This appeared to be not too difficult a task. As a practical example, they have chosen to produce an export file in that language representing the temporal information contained in a fairly representative medical letter, constructed as a temporal concentrate. The medAr data model provided the intermediary data representation. The file was produced using the standard medAr report generator. As an example, here is the past medical problems part of the letter, as it was generated automatically:

```
(EPISODE('Patient corresponding to surrogate #26')
* COMMENT Past medical problems
  (HasOccurrence OVERLAPS
    (EPISODE('psoriasis on both elbows')
      (HasOccurrence SINCE ('01/01/51'))))
  (HasOccurrence OVERLAPS
    (EPISODE('hepatitis A')
      (HasOccurrence SINCE ('01/07/59'))
      (HasOccurrence UP-TO ('12/12/59'))))
  HasOccurrence OVERLAPS
    (EVENT('appendectomy')
      (HasOccurrence AT ('02/03/78')))))
```

6. Conclusion

Concept representation in general, and medical concept representation in particular, is a critical issue of medical informatics from many points of view. Since it is preferable to consider medicine not as a section of the world, but rather as a special view of the whole reality, the number of concepts theoretically to deal with, is immense. Looking from within the medical domain, three types of concepts can be identified. A first group of concepts, not surprisingly, can be identified as being 'genuine' medical, e.g. a concept such as 'surgical neck of humerus'. A second group of concepts is coming from other sciences, such as 'acoustic impedance' or 'enzyme activity'. And finally, some medical concepts are colloquial such as 'bone', 'blood', 'pain' etc.

Time, as it is used in healthcare, is difficult to categorise in one of the three classes. It definitely is a colloquial concept, but at the same time a basic physical quantity to which precise meaning (*sometimes*) can be attached. Not surprisingly, the way one deals with time in medicine (i.e. when registering patient information, reasoning about cases and diseases,...) lies between the colloquial and the precise scientific use. Time is sometimes used in the context of a measurable quantity, but in many cases it is a rather 'fuzzy' parameter, in addition used ambiguously.

The purpose of the proposed TSMI standard is to reduce ambiguity with respect to time-related information when data are exchanged amongst healthcare information systems. First comes 'understanding', then comes 'reasoning'. Although TSMI does not deal with temporal reasoning itself, it is obvious that a clear understanding of source information enhances the possibility to reason with the information obtained.

At the other hand, TSMI has been designed in such a way that users (or information systems) only are encouraged to express themselves clearly, but not forced to be more precise than they want or can be. Often, natural language expressions of time related data contain (implicitly) subjective decisions of the physician. The statement: 'The patient suffered from headache for a long time', refers to the objective duration of the headache, as well as to the judgement of the physician, namely that this duration was 'long'. This means nothing else than that this condition is referred to those, which are or used to be described as 'long lasting' in medical textbooks or descriptions. But no one can refer this duration to a precisely defined length of time. And such measure would indeed have no use at all. Fuzziness is, in this context, a desired property of the statement, and not to be confused with ambiguity.

TSMI reduces ambiguity by offering a limited, though fairly sufficient and expressive, set of basic temporal entities, with a clear description of how they are to be used. Explicit reference is the key principle, but up to the level (and not further than) the source or originator of the information intended to go.

The proposed formalism is of course not intended to be used by physicians directly. Suitable interfaces must be developed to turn statements into 'predications' as defined by TSMI. Some problems might be expected when turning natural language expressions into TSMI predications. Most of them will be related to the more rigorous meaning that is attached to certain temporal comparators than to their natural language counterparts, e.g.

'high blood pressure since birth'

is not to be translated as

(SIT('high blood pressure')(HasOccurrence SINCE ('birth'))),

as this would mean (according to the prescribed usage of the SINCE temporal comparator) that the high blood pressure started during the process of being born, and continued since then.

The most accurate representations for the example given would be:

(EPISODE('high blood pressure')(HasOccurrence FOLLOWS ('birth')))

when the measurement was done immediately after birth, or,

(EPISODE('high blood pressure')(HasOccurrence AFTER ('birth')))

when their was a time-interval of non-defined length between the observation and the last moment of the time-interval considered to be occupied by the 'birth' process.

If the originator of the information wants to stress that he considers 'birth' as an episode or a time-point, ('birth') may be replaced by EPISODE('birth') or EVENT('birth'), respectively.

TSMI also reduces ambiguity by offering a framework representing the level to which existing databases or information systems respectively express or are capable to express time-related information according to the standard. This is a suitable means to assess to what extend databases or systems may be used for temporal reasoning purposes [8–11].

Acknowledgements

TSMI was developed by CEN/TC251/PT2-017. Team members were W. Ceusters (Belgium, Project Team Leader), S. Grebermann (USA, QC), A. Rector (UK, QC), H. Olesen (Denmark, Observer), J. Bernauer (Germany), F. Buekens (The Netherlands), L. De Keyser (Belgium), G. Surján (Hungary), A. Rossi-Mori (Italy). TSMI was funded by the European Commission and the European Free Trade Association under Order Voucher M021/BC/CEN/93/17.4.1.

References

[1] F. Buekens, W. Ceusters, G. DeMoor, The explanatory role of events in causal and temporal

reasoning in medicine, Methods Inf. Med. 32 (1993) 274–278.

[2] W. Ceusters, F. Buekens, Towards a high level framework model for the description of temporal models in healthcare information systems, in: A.J. Hoopen ten, W.J. Hofdijk, W.P.A. Beckers (Eds.), Proc. MIC '92, Publicon, Rotterdam, 1992, pp. 41–50.

[3] CEN/TC251/PT2-017. TSMI: Time standard for healthcare specific problems. Document for Formal Vote. September 1995.

[4] ISO 8601: 1988, Data elements and interchange formats—Information interchange—Representation of dates and times.

[5] ISO 31-1: 1992, Quantities and units. Pt1, Space and Time.

[6] J.F. Allen, Towards a general theory of action and time, Artif. Intell. 23 (1984) 123–154.

[7] J.F. Allen, P.J. Hayes, A common-sense theory of time, in: Proc. IJCAI-85, Los Angeles, CA, 1985, pp. 528–531.

[8] R.H. Dolin, Modelling the temporal complexities of symptoms, JAMIA 2 (1995) 323–331.

[9] W.J. Long, Reasoning about state from causation and time in a medical domain, in: Proc. IAAA 1983, IEEE Society Press, 1983, pp. 251–254.

[10] T.P. Console, On the cooperation between abductive and temporal reasoning in edical diagnosis, Artif. Intell. Med. 30 (1991) 291–311.

[11] Y. Shoham, Reasoning about Change; Time and Causation from the standpoint of Artificial Intelligence, 2nd ed., The MIT Press, Cambrdige, 1989.