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Standard Method for Describing an Electronic Patient Record Template: Application of XML to Share Domain Knowledge

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Abstract: A Template Definition Language (TDL) was developed to share knowledge of how to construct an electronic patient record (EPR) template. Based on the extensible markup language XML, TDL has been designed to be independent of EPR platforms or databases. Our research of TDL was conducted through evaluation of the description of various templates in the currently available EPRs and through comparisons with some electronic clinical guidelines. We conclude that TDL is sufficient for the objective but still needs improvement of the algorithm for describing dynamic changes.

Keywords: Knowledge Representation, Computer Based Patient Records, Structured Data Entry, Extensible Markup Language (XML), Protocol Directed Care

1. Introduction

1.1 Structured Data Entry in Electronic Patient Record System

The Electronic Patient Record (EPR) system is expected to provide a number of beneficial results. For example, data from the EPR system can be applied for decision making and clinical research. The EPR can be used for remote patient care together with a health card or in the framework of telemedicine, as well as in daily hospital use. It can also be applied to hospital billing and administration and can be used for the analysis of quality of care and cost. These beneficial effects are rapidly becoming visible. To realize these effects, patient data, which are currently documented as narrative text, must be captured in coded form [1, 2].

Such benefits of the EPR, however, are not always immediately evident for physicians. Completeness and nonambiguity are essential for the use of clinical data, though structured data entry is usually time consuming for physicians. Therefore, the necessity of improved data entry methods that do not disturb the physicians workflow and that are widely acceptable, is obvious. Free-text data entry is as flexible as the handwritten approach presently used. It provides physicians with the freedom to determine the order and depth in which they want to describe data. However, it is unable to guide physicians in the construction of more complete and consistent records. Natural language processing (NLP) is not powerful enough to locate and obtain complete and essential data items. Even if the original free-text data were complete, it would still be difficult to extract standardized and structured data from the record [3].

Structured data entry (SDE) is a more promising approach. The advantage of SDE over NLP is that the process of data capturing can be influenced by implemented knowledge. Physicians can be stimulated to produce more complete records through on-line reminders and alerts.

1.2 Templates for EPR Systems

Two well-known methods used to support SDE are templates and menu-driven interfaces. A template, in this paper, is defined as a screen, designed for data entry and retrieval. The templates are prepared according to the expected patient situation and problems [4]. Templates contain a fixed number of items to be completed. These templates can present relevant medical domain knowledge and can guide physicians in entering data in a standardized way. Data entry with such templates is suitable for restricted, well-defined medical sub-domains with a predictable patient-independent pattern of information needs [5]. When the required data are less predictable and more varied, these templates tend to make data entry cumbersome, thus requiring a more dynamic type of data entry. Such type of data entry is attained by providing adaptable templates or menus, displaying only those terms that make an appropriate representation, in combination with previous input. Menu-driven data entry is an interface in which the user selects an item from a menu or a list on the screen, which may or may not produce a new list for further selection. It is more flexible than a template, but relatively time consuming.

Recently, some medical institutions reported new ideas to make their templates more flexible and acceptable to users. For example, a template which can be edited to fit the patient's problems [6, 7], a dynamically changeable template according to the physician's action or patient data [8-12], and automatic alerts or reminders [12-15]. Although the combination of templates and menu-driven interfaces may be practical, we will focus on flexible and dynamic types of templates.

1.3 Sharing EPR Templates

Constructing flexible templates, let alone fixed and/or rigid classical types of templates, is not easy. Expert knowledge of physicians in each medical specialty is indispensable, because only those experts, anxious to make standardized and consistent patient records, know what kind of data items should be recorded and in what way these data should be represented in their specific domains. It is difficult to find knowledgeable individuals in every institution and it is almost impossible to find them in every domain. If there were a common language to adequately describe detailed information, medical knowledge for constructing templates could be shared among institutions, and collaborative work on EPR systems could be encouraged. This would result in a sufficient number of templates available at various sites, thus leading to a comprehensive EPR system.

To achieve the objective of sharing knowledge, we developed a simple platform-independent language for describing the contents and structures of templates and named it Template Definition Language (TDL) [16].

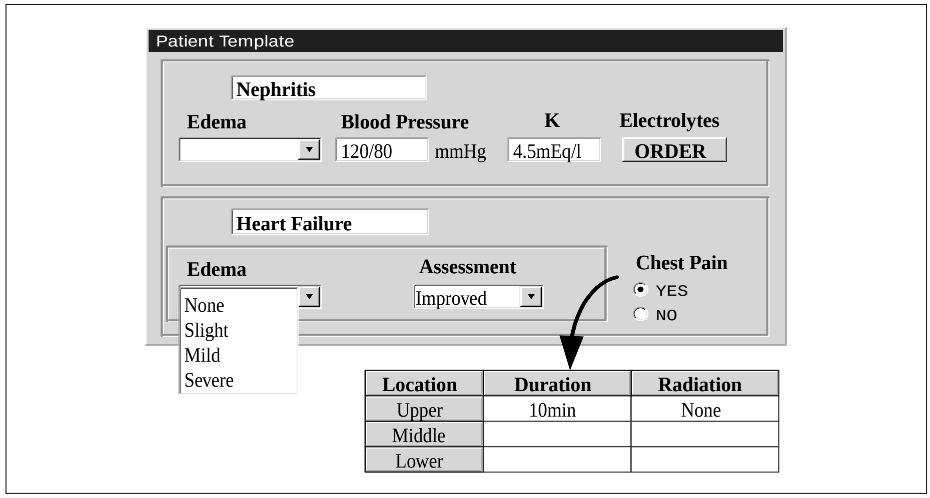

Fig. 1 Sample screen of a template.
This template contains several items that are selected for the follow-up of two problems: nephritis and heart failure. The item Edema is selected for both problems and the value of the item is chosen from the list. A value for blood pressure must be entered manually, while in the item K, the value comes from a database. In the item Electrolyte, the button ORDER is linked to an order-entry system. When the item Chest Pain is checked "yes", a new window comes up for detailed data entry.

2. Methods

2.1 Steps of TDL Development

There are five steps to develop TDL and achieve knowledge sharing.

1. Developing an intermediate language for describing the contents and structure of a template (TDL).

2. Describing templates with TDL to share various EPR systems.

3. Translation of a TDL document into other local EPR applications through manual encoding.

4. Developing a TDL document editor so that physicians can edit TDL documents without assistance from a TDL expert.

5. Developing a TDL document translator so that physicians can implement a template described in a TDL document into the local EPR application.

Using the TDL editor and translator, physicians can generate templates by themselves.

In this paper we examine the first and second step of this process. A TDL Working Group (one of the special research interest groups in the Japanese Association of Medical Informatics) began developing these steps in 1997, and decided in 1998 to use the extensible markup language (XML) to attain these objectives [17].

2.2 Requirements for TDL

Throughout our discussion, the requirements of TDL were defined as follows:

1. TDL should be independent of EPR platforms and various types of databases. Several medical institutions have developed templates using different software or hardware platforms and applying different types of databases, such as relational, object-oriented, or in the M language. Therefore, TDL should be an intermediate language for describing knowledge, to assure independence from such platforms or database types.

2. TDL should be able to describe dynamic changes of actual templates. Templates will change dynamically according to entered data or existing values referred from a database. Therefore, TDL should describe an algorithm to specify the conditions and the results.

3. TDL should be able to describe data items (an individual data unit in an EPR system) to include its attributes, hierarchical structures, and a list of selectable values. Template models vary in granularity of data items and have different numbers of hierarchical layers. Therefore, TDL should describe these variations, as well as data values of various sources such as category, classification, and terminology.

It is assumed that the users who describe templates using TDL are not computer experts, but rather physicians, nurses, or other medical practitioners. Therefore, TDL should be simple and easy to understand for appropriately describing templates.

3. Results

3.1 Maintenance and Index Information

A TDL document has a MAINTENANCE_BODY and a LIBRARY_BODY. We applied both the maintenance category and the library category of the Medical Logic Module (MLM), which will be discussed later [18, 19]. They furnish users, who want to introduce a template to their own institution, with the necessary documentation.

Table 1 An essential part of the Document Type Definition of TDL.

```
<!ELEMENT TEMPLATE_KNOWLEDGE (TEMPLATE+)>
<!ELEMENT TEMPLATE (TITLE? | TYPE? | (PANEL | ATOM)+)>
<!ATTLIST TEMPLATE TEMPLATE_CODE CDATA #IMPLIED PANEL_ID ID #REQUIRED>
<!ELEMENT TITLE  (#PCDATA)>
<!ELEMENT TYPE (#PCDATA)>
<!ELEMENT PANEL (TITLE? | TYPE? | (PANEL | ATOM)+)>
<!ATTLIST PANEL PANEL_ID ID #IMPLIED  PANEL_CODE CDATA #IMPLIED>
<!ELEMENT ATOM (TITLE? | TYPE? | (PANEL | (LOCATION?,REPET,VALUE,CAT?,UNIT?,URI?))+)>
<!ATTLIST ATOM ATOM_CODE CDATA #IMPLIED ATOM_ID ID #REQUIRED ATOM_RID IDREF #IMPLIED>
<!ELEMENT LOCATION (#PCDATA)>
<!ELEMENT REPET (#PCDATA)>
<!ELEMENT VALUE (#PCDATA)>
<!ELEMENT CAT (#PCDATA)>
<!ELEMENT UNIT (#PCDATA)>
<!ELEMENT URI (#PCDATA)>
```

Table 2 A part of the TDL document for the sample template.

```
<PANEL PANEL_CODE=D7-12018  PANEL_ID=2>
    <TITLE>Nephritis</TITLE><TYPE>Follow up</TYPE>
    <ATOM ATOM_CODE=F-18440  ATOM_ID=1>
        <TITLE>Edema</TITLE><TYPE> Objective Observation </TYPE>
        <REPET>O</REPET><VALUE>List</VALUE><CAT>None, Slight, Mild, Severe</CAT>
    </ATOM>
    <ATOM ATOM_CODE=F-31000 ATOM_ID=2>
        <TITLE>Blood Pressure</TITLE><TYPE>Objective Observation</TYPE>
        <REPET>O</REPET><VALUE>String</VALUE><UNIT>mmHg</UNIT>
    </ATOM>
    <ATOM ATOM_CODE=P3-73850 ATOM_ID=3>
        <TITLE>K</TITLE><TYPE>Laboratory Data</TYPE>
        <REPET>O</REPET><VALUE>DB</VALUE>
    </ATOM>
    <ATOM ATOM_CODE=P3-72710 ATOM_ID=4>
        <TITLE>Electrolytes</TITLE><TYPE> Laboratory Data </TYPE>
        <REPET>O</REPET><VALUE>OE</VALUE>
    </ATOM>
</PANEL>
<PANEL PANEL_CODE=D3-16000 PANEL_ID=3>
    <TITLE>Heart Failure</TITLE><TYPE>Follow up</TYPE>
    <PANEL PANEL_CODE= PANEL_ID=4>
        <ATOM ATOM_RID=1/>
        <ATOM ATOM_CODE=D7-00030 ATOM_ID=31>
            <TITLE>Assessment</TITLE> <TYPE> Assessment</TYPE>
            <REPET>O</REPET><VALUE>List</VALUE>
            <CAT>Improved,Unchanged, Worsened</CAT>
        </ATOM>
    </PANEL>
    <ATOM ATOM_CODE=F-37000 ATOM_ID=32>
        <TITLE>Chest Pain</TITLE><TYPE> Subjective Observation </TYPE>
        <REPET>ZO</REPET><VALUE>List</VALUE><CAT>YES, NO</CAT>
<!--  Selected value of ATOM ATOM_ID=32 is "YES", then show PANEL PANEL_ID=5 . - - !>
            <PANEL PANEL_CODE= PANEL_ID=5>
                <LOCATION>Upper,Middle,Lower</LOCATION><REPET>ZM</REPET>
                <ATOM ATOM_ID=35>
                    <TITLE>Duration</TITLE><TYPE> Subjective Observation </TYPE>
                    <REPET>O</REPET><VALUE>String</VALUE>
                </ATOM>
                <ATOM ATOM_ID=34>
                    <TITLE>Radiation</TITLE><TYPE> Subjective Observation </TYPE>
                    <REPET>O</REPET><VALUE>String</VALUE>
                </ATOM>
        </PANEL>
    </ATOM>
</PANEL>
```

MAINTENANCE_BODY is used for documentation about maintenance and change control of a TDL document. LIBRARY_BODY provides the users with predefined explanatory information and references to the literature, and facilitates searching for TDL documents.

CODE_SET is added to the MAINTENANCE_BODY to specify the standard code system the author uses in the document. VALIDATION_SLOT is expressed as an ATTRIBUTE of the MAINTENANCE_BODY. VALIDATION_SLOT specifies the validation status of the template and values used in the VALIDATION_SLOT are as follows: (1) production – approved for use in the clinical system, (2) research – approved for use in a research study, (3) testing – for debugging, default initial value, (4) expired – out of date, no longer in clinical use. The domain specialist of the receiving institution must set the validation status.

3.2 Basic Components

Basic components of a template are represented as ATOM. An essential part of a document type definition in TDL is shown in Table 1. TITLE in an ATOM defines the name of the ATOM. TYPE in an ATOM defines the category of the ATOM. ATOM is classified into several categories, such as subjective observation, objective observation, laboratory data, assessment, plan, etc. LOCATION specifies a part of the body where an event occurs related to the ATOM. If the event happens in more than one part of the body, we can record information for each part.

REPET represents both R/O (required/optional) and allowance of repetition of the ATOM value. Values of REPET are categorized as "O" (one), "ZO" (zero or one), "OM" (one or more), and "ZM" (zero or more).

VALUE defines a data type of the ATOM and includes "List", "String", "Numeric", "VAS" (visual analog scale), "File", "DB" (database), "OE" (order entry), and a name of classification or terminology. When VALUE equals "List", the selectable values are defined in CAT. "File" and "DB" mean that the value refers to other resources, such as files or data values from another system. "OE" means that the item is one of the items of the local order-entry system and that the value is transferred to the system. If the receiving institution does not have such an order-entry system or such an item in their system, “OE” is regarded as “String”. When data are selected from a classification or terminology, the name is specified such as “ICD9-CM”,“ICD10”, or “SNOMED INTERNATIONAL Ver3.4”.

CAT defines choices of data values or the selectable code range. For example, if the TITLE of the ATOM is “severity of arthralgia” and the VALUE is “List”, the value of the CAT would be “none, slight, mild, moderate, severe”. If the TITLE of the ATOM is “systemic connective tissue disorders” and the VALUE is “ICD10”, the value of the CAT would be ”M30 : M36”.

UNIT is used when a unit of the value is to be specified. For example, when users have to enter some numerical data directly from the terminal, unlike the data transferred from the database, the template screen should show the unit of the value.

URI is used to define the resource location when the VALUE is “File” or “DB”.

ATTRIBUTEs of the ATOM are ATOM_CODE, ATOM_ID, and ATOM_RID. When local and non-standardized terms are required to be used as the ATOM title, the corresponding code is set in an ATOM_CODE from a code system that is specified as the CODE_SET, as previously mentioned. The ATOM_ID is of the ID type ATTRIBUTE and identifies the ATOM in a TDL document. The ATOM_RID is of IDREF type and is used to refer to the ATOM that has already been defined with an ATOM_ID within the same document. When a completely identical ATOM is used for different places, it is not necessary to define it twice.

3.3 Clustering the Components

Data items are often arranged as groups on a screen according to the item categories. PANEL defines the clustering of components in a template. This element represents both partitions on the screen and the semantic difference of the components. PANEL consists of TITLE and PANEL. TITLE in a PANEL is the name of the PANEL. PANEL has the attributes PANEL_ID and PANEL_CODE, with PANEL_-CODE indicating the relation to the coding system.

TEMPLATE is defined as the most basic subclass of PANEL. TITLE in a TEMPLATE defines the name of the TEMPLATE. TYPE in the TEMPLATE is used to define the categories of templates. The hierarchical structure of data items is given with the nesting of ATOM and PANEL (Table 2).

3.4 Dynamic Change of Screen

Templates may change dynamically, triggered by the physician’s action or the patient’s data. TDL is required as a method for describing these kinds of functions including automatic alerts and reminders and, in short, an algorithm for dynamic changing of screens. In this version of TDL, we decided that the rule is to be described in COMMENTS using free text or the Arden Syntax, similar to the knowledge slots in an MLM.

4. Describing Currently Available EPR Models

The Evaluation results of the TDL using some examples of EPR templates designed by three institutions are as follows.

4.1 Chiba University’s Model [6]

A basic component of their template is called Check Item. The Check Item is an individual data unit to be mapped onto a template. It defines how to represent attributes of the item, such as location, area, severity, alleviating factor, and aggravation factor, and is designed explicitly for SDE. A Check Item is designed independently of a template title (i.e., problem) for consistency of patient data throughout various templates. For example, the Check Item for “dyspnea” should be used in the template for heart failure and also in that of lung cancer.

A Check Item has a two-layer structure for data entry with different data granularity. Check Items of this model are described with ATOM. In other words, an ATOM and the subelement ATOM represent two layers of each Check Item.

The most prominent feature of the template developed by Chiba University is tailoring. Tailoring in this context means that a physician modifies templates for each individual patient. Many standard templates are prepared for patient problem, which are primarily provided in the default screen. The template, after customization for a patient, is called a Patient Template. The users are allowed to generate a Patient Template modifying Standard Templates.

The description of a mechanism that customizes a standard template into a patient template is not required with TDL because the mechanism depends on the local EPR platform. However, the contents and structure of a template, both standard and patient-dedicated ones are well represented.

4.2 Osaka University’s Model [8]

The basic concept of the EPR template in Osaka University is similar to that of TDL, with the exception that they defined a “template” as a singular descriptive unit, i.e., symptom, physical finding, examination report, etc. Therefore their “template” is compatible with the Check Item in the Chiba University Model and is described with ATOM and its subelements of TDL.

The most prominent feature of a “template” in this model is a dynamic change of screens according to entered data. When a “template” is selected on a screen, the top layer of elements appears and allows user data entry. When the data value meets specific criteria, the “template” shows the second layer for precise data entry. This mechanism allows physicians to skip negligible items.

TDL can be used to describe many aspects of the Osaka University Model. Dynamic change in a template can also be represented by the method mentioned in section 3.4.

4.3 Erasmus University’s Model (ORCA) [3,10,20]

The Open Record for Care (ORCA) is a powerful EPR system developed by Erasmus University in Rotterdam. The most prominent feature of ORCA is the support of knowledge-driven data entry. Based on the descriptional knowledge base, which contains medical concepts (terms) and their semantic network, ORCA provides programs to support menu-driven SDEs. To enhance the efficiency of the SDE interface for daily routine, it also provides a form that is a custom view on the knowledge base and compatible with the concept of templates in TDL. Items (concepts) from their descriptional knowledge base can be added to a form which provides direct shortcuts to the SDE interface, in the sense that the user does not have to navigate to the concept to be described.

We estimated a hypothetical template (form) in ORCA, based on their reports and what appeared in their demonstration video. The data items and structures as well as a part of the descriptional knowledge base used in ORCA were represented with this TDL. TDL describes properties of medical concepts using ATOM and its subelements, however, other than a simple parent-child relationship it lacks an explicit method to describe relationships between concepts.

5. Discussion

5.1 Platform Independence

For knowledge sharing, it is necessary for TDL to be platform independent. To get independence from both the hardware platform and the EPR application-software environment, TDL leaves detailed definitions of user-interface and screen designs to the local system. Therefore, in using a single TDL document, the users can choose either a check box or a menu list to present alternatives. On the other hand, the users have to give additional information to the TDL document for implementing it into a local EPR system. In this version of TDL, we do not intend to display a template directly from a TDL document, due to the limited datatyping facilities in XML and the need for a stylesheet.

There are three other points left up to the local system for platform independence.

1. Time-oriented representation of data is critical to make good use of clinical data. The time stamp is indispensable to an EPR and it should automatically be added to entered data by the local system. If an event requires that the specific date and time be recorded, the subelement ATOM, which represents date and time, should be used beside the ATOM to represent the event.

2. An EPR system and an order-entry system should be used jointly at the point of care. An individual producing a template may include order-entry items in the template. Therefore, VALUE "OE" is prepared. Realistically, more precise information would be necessary to attain a linkage between an EPR template and an order-entry system; however, this additional information is not a requisite of TDL.

3. It is widely accepted that medical narratives are best presented in natural fluent prose to facilitate reading [4]. Although the mechanisms that regenerate free text from structurally entered data are desirable, we have decided to leave these mechanisms to the local system.

5.2 Relationship Between Elements

The semantic relationship between the elements within a TDL document is simply that of a parent-child relationship, which is described with PANEL and their subelements. Instead of describing other relations, TDL has linkages to external concepts or terminology. By the value of ATOM_CODE or PANEL_CODE, TDL makes a connection between an ATOM and a code of a classification system. Therefore, the semantics can be used through such a TDL linkage mechanism.

5.3 Rules for Dynamic Changing of a Template

The user's data entry or other user actions should trigger the action, not only showing messages on the screen, but also changing the screen design. The description of the rule should represent judgment criteria on changes of the template after being triggered. Data from the patient database may be required as parameters of the rule.

The Arden Syntax for Medical Logic Modules (ASTM E 31.15) is one of the most appropriate and suitable standards that meets these requirements [18, 19]. In MLM the input is usually a set of patient data from the database, and the output is messages to the users. Therefore MLM should be extended to carry out a TDL-defined action. Chaining of multiple MLMs together, which is not well supported by the current MLM, is required.

A script can be described in the extensible style language (XSL) document for XML [21, 22]. The ECMA Script standard provides the basis for the XSL scripting language, and the script is the standardized specification of JavaScript. Control of the screen and processing of the data entered by users is expressed with the ECMA Script. However, because handling data from a patient database is difficult, the adoption of the ECMA Script to describe the rule would require an XSL document to be added to the TDL document. We are expecting a new version of Arden Syntax and will decide whether it can be used in TDL.

5.4 Comparison with Other Approaches

The Problem Knowledge Coupler (PKC) system, developed by Weed et al. [2] is a computerized medical record as well as a problem-solving and decision-support software. PKC contains almost the same concept as that of the template; however, while the couplers can be shared among same systems, they can not be shared among the different EPR systems.

Data entry and Reporting Markup Language (DRML) was developed by Kahn, et al. [23]. Their SDE method is classified as a template. DRML, like TDL, is independent of EPR platforms and various types of databases, but it cannot describe dynamic template changes. Although they plan to develop an interactive template, using Java applets, this may confine its usage to HTTP platforms. DRML has some limitations in describing item structures, including item values such as lists of choices. Kahn et al. use three types of fundamental data items: binary, numeric, and textual. When a list of selectable values should be expressed in a template using DRML, each of the values will be expressed as binary type along with its name.

The goal of the Guideline Interchange Format (GLIF), developed by members of the InterMed Collaboratory, is to establish shareable guideline representation [24]. Guidelines are systematically developed statements, which assist physicians and patients on decisions about appropriate health care. On the other hand, a template is used as data entry and data browser design and is regarded as the user interface of the computerized guideline. GLIF, like TDL, is also independent of EPR platforms and various types of databases. For the collection of patient data, the class Action Step of the class Guideline Step in GLIF models is used. The class does not have any attributes for screen design; therefore, GLIF does not describe structures of data items. For this reason, GLIF is not expressive on dynamic changes of templates, triggered by data either entered by a user or referred to from a database, though it is expressive on dynamic change of guidelines.

6. Conclusions

Until now, there was nothing available for the exchange of the contents and structure of a template other than free-format paper documents. There was no standard expression and there existed even confusion of the terms concerning templates. Our version of TDL has solved this problem. It can describe the contents and structure of a template, which may be exchanged between institutions, vendors and platforms.

Standardization of ATOM items (title, value, and other attributes) of templates is part of the value of TDL. Ideally, these ATOM items should be standardized, but this takes time and requires further discussion. We do not aim for standardization of the templates. TDL itself does not regulate the contents of templates. Rather, TDL differentiates between various kinds of templates, even those having the same title (including problem), and makes apparent the differences between medical practices. TDL will also provoke discussions on such issues.

We look forward to rigorous discussion on the standardization of the EPR system and pertaining materials, through utilization of TDL.

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