Assessment of MHB: an intermediate language for the representation of medical guidelines

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Abstract. The goal of the study described in this research paper is the assessment of a recently developed intermediate representation language, called MHB (Many-Headed Bridge), as an intermediate step within the clinical guidelines formalisation process. We qualitatively assess (1) whether it makes easier the formalisation of the guideline and, (2) to which degree MHB covers written text guideline features. For the assessment, we apply a multi-step formalisation process. In this practical approach, we have based our work on the CBO evidence-based clinical guideline for the treatment of the breast carcinoma.

1 Introduction

According to [1] clinical guidelines are ”systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances”. Such guidelines are based on the best empirical evidence available at the moment [2].

During the last decade, studies have shown the benefits of using clinical guidelines in the daily practice of medicine. In recent years, the effort in the development, implementation and dissemination of evidence-based clinical guidelines has increased considerably in many countries around the world [3]. The main reason is that guidelines depict the optimal assistance/care for patients and, when properly applied, it is assumed that they improve the quality of health care and services. Moreover, medical guidelines are supposed to make health care more consistent and efficient and, thereby it serves to bridge the gap between what medical experts do and what scientific evidence and experience supports.

As a consequence of this growing up of clinical guidelines, there are several reasons to bring guidelines into a computer-processable form. One of them, according to the explanation above, is to make them more accessible and sharable using standards, such as XML or HL7. Another reason to make a guideline computer executable is to provide practitioners with the most suitable recommendations at the right time at the point of care within the context of a specific patient under certain specific circumstances [4].

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In fact, several formal languages have been developed for the specific representation of medical knowledge. In spite of these efforts, they are still too far from written text guidelines. Protocure II suggests the implementation of an intermediate representation language, between written text and guideline representation languages. It is MHB (Many-Headed Bridge) [5], developed in the framework of this project. A different approach is the one proposed by DeGeL [6] which does not use an intermediate representation (IR) language but a semi-structured representation corresponding to the top level concepts of a semi-formal language such as Asbru or GEM.

The task presented in this paper is a qualitative assessment of MHB rather than a quantitative one. Indeed, it is still too early to conduct experiments that allow us to draw more general and quantitative conclusions. We develop this qualitative assessment by means of a two-step formalisation of a specific clinical practice guideline, "Guideline for the Treatment of Breast Carcinoma", provided by CBO[4]. The main reason for using an intermediate step is due to the large gap between paper guideline [5] and its formal version. In this sense, our purpose is to evaluate how suitable MHB is, as an additional step, in order to close this bridge. We focus on the assessment of the following aspects: (1) whether it makes the formalisation of the guideline easier and, (2) to which degree MHB covers written text guideline features.

The main motivation is led by the novelty of MHB. Its usage drives a productive feedback between users and developers, and it seems relevant to determine if it is suitable for its intended task, which is modelling medical knowledge precise enough to be used by medical experts, although not formal as a computer-processable representation.

The paper consists of an introduction to MHB in Section 2, while Section 4 provides a sketch of Asbru. According to our two-step process, in Section 3, we focus on going from the guideline to MHB, its difficulties and conclusions; and, in Section 5, we deal with the second step about the Asbru model and difficulties found. It also remarks some conclusions and shows some issues for future work.

2 Introduction to MHB

MHB [5] is an intermediate representation language. It considers, as a *chunk*, related bits of information in natural language. With a *chunk* we represent, in parallel, one or more of the eight dimensions provided by the language. These dimensions are known as *control*, *data*, *time*, *evidence*, *background*, *resources*, *patient-aspects* and *structure*. Each dimension has its own aspects and (optional / mandatory) attributes.

The **control** dimension deals with statements about *when* to do *what* by means of: (i) *Decisions*: the MHB basic structure of a decision is `if-then`, but it is too simple when describing more than one option. For those cases, MHB provides the `option-group` element in order to grouping several `if-then` elements, which can exclude each other or not, or specify the selection process in the optional attribute `other-selection-specification`; (ii) by the `decomposition` element, MHB decomposes any task into children tasks defining constraints on their execution relative to each other using the `ordering` attribute; finally, (iii) MHB provides the element `repetition` for those cases in which a task is performed more than once.

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MHB models data flow with **data** dimension, distinguishing among the following aspects: (i) the `definition` element defines one data entity; (ii) the `usage` element names a piece of information used in the chunk; (iii) the `input` element indicates that certain information is supplied by the user; and (iv) the `abstraction` element depicts how one data is calculated based on others in a declarative way.

Both data and control flow may have temporal aspects. The **time** dimension let us model these temporal aspects in a qualitative (e.g. before/after relations) or quantitative (indicating the starting/finishing time and/or duration of an interval) way.

In evidence-based guidelines, statements are based on a specific evidence degree. Although their structure may vary, there are parts that appear very often together in these statements. They are covered by the MHB **evidence** dimension, e.g.: the `grade` and `level` of evidence according to the grading scheme of the guideline or, the identifier (`is-based-on`) of another different chunk, to make other evidence references explicit.

The **background** dimension tries to model what we know as background information, for example: (i) `intention` of actions or recommendations; (ii) `effect`, which establishes cause-effect relations; (iii) `educational` gives details of a recommendation that do not have direct link to any activity; (iv) justification of a particular statement with the `explanation` element.

The aspects related to the resources consumed by each action are gathered in the **resources** dimension. Those related to the patient are in the **patient-aspects** dimension. Finally, **structure** dimension describes the position of the statements by means of the `status` of the chunk. The ones pre-defined by MHB are: introduction, definition, scientific-justification, conclusions, further-considerations, recommendations, table and, other.

From the practical side, the following example illustrates how a piece of information from the guideline can be modelled into MHB. Obviously, this example does not cover all dimensions and aspects provided by MHB.

Since the treatment of choice is usually neoadjuvant chemotherapy, and since it may not be possible to collect live tumour tissue after chemotherapy, it is advisable to establish a histological diagnosis by means of a core biopsy, where the hormone receptor status and oder prognostic characteristics can also be analysed. It is also advisable to confirm the presence of lymph node metastases with (possibly ultrasound-guided) FNAC [5].

We distinguish three different pieces of information, although they are intertwined. The first one *"Since the treatment of choice ..."* is an explanation about what is coming next *"... it is advisable to establish ..."*. We model the explanation as a background dimension. The other two sentences say that there are two advisable diagnosis procedures *"...core biopsy ... and ... FNAC ..."*. In this case, we use the decomposition aspect of the control dimension, consisting of two child tasks (core biopsy and FNAC) which are applied sequentially though the order is not relevant; that is the reason why we use "any-order". Both children are single actions, i.e., `clinical-activity`. The corresponding MHB code is showed in Table 1. Notice that, although MHB is based on the standard XML, in this paper we use a tabular format to increase readability.

[5] Fine-needle aspiration cytology

CHUNK	core-biopsy&FNAC		
background	explanation	information	Since the treatment of choice is usually neoadjuvant chemotherapy, and since it may not be possible to collect live tumour tissue after chemotherapy
control	decomposition	parent-task	advisable-procedures
		ordering	any-order
		child-task(s)	core-biopsy FNAC
structure		status	scientific-justification

Table 1. Example of MHB code: decomposition

3 From the guideline text to MHB

For the construction of the MHB representation, we use the Guideline Mark-up Tool (GMT) [7]. Working with GMT, we deal with HTML and XML files at the same time. Our approach is a two-step process: in a first step, described in this Section, the original guideline text, in HTML, is displayed at the left-hand side and the MHB model, in XML, at the right-hand side. In a second step, the MHB model is displayed at the left-hand side and a new formal version (the Asbru model) is showed at the right-hand side. Besides, GMT allows us to link modelled knowledge from both files on the screen to facilitate navigation.

To model a guideline in MHB, firstly, we need to identify procedural knowledge. According to the medical and computer expert's opinion, it is located mainly in conclusion and recommendation parts. However, even this first step was not as easy as expected. During the modelling task, we found out new procedural knowledge outside these parts; on the other hand, we also faced troubles with the formatting of the guideline due to the fact that it has been developed by different authors and, consequently, the format differs from one to another, what confuses the knowledge engineer. Needless to say that, in all these decisions and clarifications we needed medical experts.

3.1 Anomalies

At this stage, pre-processing the medical guideline and modelling it into MHB, we encountered some problematic points at the guideline text level, called from now on anomalies. To facilitate matters, we cluster these anomalies into four main categories: ambiguity, incompleteness, inconsistency and terminology.

We identify **ambiguity** on those statements that can be interpreted differently depending on the point of view or on the background/commonsense knowledge. As an example, we show you the structure of the recommendations for N+ (node positive) patients content:

In principle, all patients with N+ breast cancer are eligible for adjuvant systemic therapy. The choice of therapy ...

** Premenopausal N+ patients are advised to undergo ...*

** Postmenopausal N+ patients aged 50-69 years with ...*

Postmenopausal N+ patients above 50 years of age with an ...

Chemotherapy should, preferable, consist of four to six courses of an anthracycline-containing chemotherapy ...

The first paragraph refers to all patients with N+ breast cancer and, the following two points refer to premenopausal and postmenopausal N+ patients, respectively.

Then, another paragraph about postmenopausal N+ patients follows. Finally, the last paragraph does not say anything about the menopausal status of the patients. The ambiguity appears when we need to determine whether this final paragraph refers to postmenopausal patients, since the prior paragraph talks about this group, or it is independent on the menopausal status, because it is a completely different paragraph.

We define **incompleteness** as the lack of information to totally describe, for instance, an action, definition or decision. For example, the guideline says that less intensive treatment consists of hormone therapy and locoregional treatment. Nevertheless, it does not say anything about the ordering. Thus, completeness is not achieved.

Inconsistency means the contradiction between two or more pieces of information located in different parts of the guideline. For instance, we detected a different ordering between two therapies (endocrine therapy and chemotherapy) under the same conditions but in different locations within the text.

The last anomaly is the lack of standards in **terminology**. It has to do with different terms, that in a particular context mean the same, but not necessarily in other contexts. For example: we identify endocrine therapy and hormone therapy (synonyms), and tamoxifen and the ovarian function suppression that are types of the endocrine/hormone therapy. Under certain contexts, they all are used as synonyms although the last ones are instances. This implies a terminological modelling consensus, so that we do not model the same concept using different terms and, then, we avoid future misunderstandings.

A different kind of difficulty, but not less controversial, is the **redundancy**. Sometimes knowledge is expressed in a different way but keeping the same meaning. In those cases, we should decide whether we model it twice at the intermediate level and treat the redundancy later on in the formal representation or whether we avoid the redundancy at this stage. From our point of view, the most logical option is to avoid redundancy as soon as we detect it. Otherwise, we are duplicating information, making difficult the maintenance and further treatment of this information.

3.2 MHB Extensions and improvements

During the MHB representation we found out some aspects that were not available in the language, which served to improve it. We list the most relevant:

- **Single action**. There was no MHB construct to express single actions made by a doctor, such as "FNAC". A new element *clinical-activity* was included for this purpose.
- **Context**. There was no MHB construct to determine the context of a piece of information, since the meaning of some information may change depending on the context. The *context* attribute was included in *chunk* and *chunk-group* elements.
- **General relations**. The only kind of relationship that could be explained was cause-effect. A new *relation* element was included to express more general types of relations, such as a higher increase.

This additions actually increased the MHB **coverage** of the guideline features. In spite of them, we still find knowledge that cannot be captured by MHB, at least not in enough detail.

3.3 Conclusions

This MHB modelling has allowed us to draw conclusions both from the medical users perspective and from the modellers perspective.

From the medical point of view, MHB modelling is not as easy as expected since it was supposed to be used by medical professionals. We provided medical experts with GMT and MHB, and they tried this technology, concluding that they were not comfortable with it. fact, doctors declare that it is neither easy nor intuitive to use for To solve this problem we propose the implementation of a user-friendly interface instead of the XML code, which cause an unpleasant perception for them. Indeed, this proposal was accepted by medical experts.

From the modellers' point of view, we conclude with some limitations of MHB:

- MHB is too expressive and gives the user too much freedom at the modelling time. Nevertheless, side-effects from this are: duplicating identifiers if the user does not use macros, modelling a cause-effect (e.g. chemotherapy increases survival percentage) as a qualitative-relation or modelling a control element without including data items, loosing data flow representation.
- Lack of the representation of adjectives expressing when an action is going to take place. For example, all these three terms, neoadjuvant chemotherapy, (neo)adjuvant chemotherapy and adjuvant chemotherapy, refer to chemotherapy. The adjective only points out when it has to be applied (before or after surgery). One possibility would be to include "IS-A" relations, using the *relation* element. This proposal in its own has no effect because ontologies are not integrated in MHB. Consequently, it should have to be studied the possibility of connecting MHB models with ontologies.
- Finally, there is no way of knowing automatically whether a piece of information has already been modelled. It depends on the methodological and strict way of working of the knowledge engineer and on his/her skills.

4 Introduction to Asbru

Asbru is a guideline representation language for medical guidelines and protocols. The main Asbru [8] features are the specification of intentions, the expressivity to represent temporal aspects, and the hierarchical representation of a guideline as a plan skeleton.

Within an Asbru plan, we may find *preferences*, *intentions*, *conditions*, *effects* and *plan-body*. We only describe the most frequently used feature in our case. For a more detailed information refer to [9].

Intentions are high-level goals of a plan with regard to certain actions or states, which can be intermediate or overall and should be achieved, maintained or avoided.

Conditions guide the transitions among the states of a plan (started, suspended, reactivated, aborted or completed). Asbru defines different types of conditions. Next we point out the most important types: *filter-conditions* must be true before the plan is started; *abort-conditions* determine when an already started plan must be aborted; *complete-conditions* indicate when a plan in execution can complete successfully; *activate-conditions* enforce a user confirmation before the plan is started when its value is "manual", if it is not the case, it means it has the "automatic" value.

Effects describe the relationship between plan arguments and measurable parameters and may include a degree of certainty, e.g. applying chemotherapy causes neutropenia in the patients treated with an unknown likelihood.

A **Plan body** contains the plans and/or actions to be performed when the parent plan is started. Next we list the main types of plan-body:

1. A *user-performed* plan represents an action performed by the user.
2. A *single step* could be activation of a subplan, assignment of a variable, request for an input or if-then-else statement.
3. *subplans* are a set of plans/actions within a parent plan, which are performed in a certain order: sequentially, in parallel, any-order (in any sequential order) and unordered (in any possible order).
4. A *cyclical* plan expresses a repetition of actions, as long as conditions hold or a maximum number of times, for instance.

For subplans, Asbru allows to specify a waiting strategy, e.g. *wait-for all*/*wait-for one*, to specify which subplans must be completed so that the parent-plan completes successfully, as well.

The most important Asbru feature is the specification of temporal aspects. It is provided by the *time-annotation* element, which defines the temporal constraints for the execution of an action, e.g: (1) in which interval the action must start (earliest and latest time points), (2) in which interval it must end (earliest and latest time points), and (3) its duration (minimum and maximum bounds).

5 From MHB to Asbru

In this section we present the second step of our approach: moving from MHB to Asbru. At this point we have at our disposal a task hierarchy from the MHB model, which provides almost the basic structure of the Asbru version, all data items involved in the execution of the guideline from the MHB model and, the MHB model itself. Notice that a priority for this is that the MHB modeller carefully chooses the different identifiers used throughout the model. Therefore, we have a good starting point for creating an Asbru model.

For the formalisation of control flow, we focus on `decomposition`, `if-then` and `option-group`, from MHB, (control-dimension) as the main elements of Asbru plans. Firstly, we adjust the MHB task hierarchy to the Asbru plan skeleton. Afterwards, we model and add all the additional information which is explicitly modelled in MHB to the Asbru plans, such as conditions, preconditions and data items.

5.1 Difficulties and improvements

In this section, we explain the difficulties arisen during the translation from MHB into Asbru and those coming from the fine-tuning of the Asbru model. Besides, we also mention the improvements we get in the Asbru model with regard to the MHB model.

Difficulties coming from the translation from MHB into Asbru From our experience, obtaining the Asbru plan hierarchy from the MHB plan structure is not straightforward and we have found out that it highly depends on the MHB modeller's skills. Generally speaking, basic knowledge in computer science and programming results in a detailed MHB task hierarchy, from the Asbru point of view. Therefore, the most well-structured, synthesised and less coarse is the MHB model the most easy is building the Asbru plan hierarchy. This is in connection with the previous conclusion about the MHB usage freedom.

For instance, the following piece of information:

Cytology may generate false-positive results, particularly in a radiated area. Just like with the diagnosis of locally advanced breast cancer, a staging examination is recommended, consisting of a chest X-ray, bone scintigraphy, ultrasound of the liver en a contralateral mammogram to exclude synchronous distant metastases and or a contralateral tumour. In the event of a local recurrence, lymphogenous metastases may also occur in the contralateral axilla or parasternally. Physical examination should be aimed at this.

could be modelled in MHB as an `if-then` aspect, i.e., *if* the condition ”when suspecting locoregional recurrence” is true, the *result* is that ”a staging examination is recommended, consisting of a chest X-ray, [. . .]”.

Nevertheless, this way of modelling is too coarse and, although it is allowed by MHB, will be useless in the Asbru formalisation, since there is little pre-processing of the original information.

The alternative in Table 2 gives a detailed representation. When using it in the transformation towards Asbru could easily identify:

- Intention of excluding synchronous distant metastases in the `staging-investigation` plan (Table 2).
- The `staging-investigation` plan consists of three subplans: `chest X-ray`, `bone-scintigraphy` and `US-of-the-liver` (Table 2).

CHUNK	staging-investigation-definition		
background	intention	goal	exclude synchronous distant metastases
		modifier	achieve
control	decomposition	parent-task	staging-investigation
		child-task(s)	chest X-ray
			bone-scintigraphy
			US-of-the-liver
structure		status	scientific-justification

Table 2. Refined version of the MHB code

Difficulties coming from the Asbru fine-tuning It was mentioned in Section 4 that Asbru is very powerful at representing temporal aspects. Nevertheless, it entails a more complex modelling. The main difficulties we have experienced are how to represent time-annotations, mostly, within cyclical plans. For example, the following information:

The following follow-up schedule is recommended:
- first year: once every three months;
- second year: once every six months;
- subsequently: annually.

corresponds to the Asbru code from Tables 3 - 4. Note that although Asbru has an XML syntax, we use again a tabular format to make it readable.

PLAN	follow-up-programme			
subplans	type	sequentially		
	plan-activation	first-year-follow-up		
		time-annotation	min-duration	12 mon
			max-duration	12 mon
		plan-state-transition	determination-of-mammography-cycle-manual	
	plan-activation	second-year-follow-up		
		...		

Table 3. Example of Asbru: time-annotations and cyclical-plans (a)

PLAN	first-year-follow-up		
cyclical-plan	time-annotation	earliest-start	0 days
		latest-start	15 days
	cyclical-time-points	plan-state-transition	self
		offset	0 days
		frequency	3 mon
	cyclical-plan-body	plan-activation	follow-up
		times-completed	4

Table 4. Example of Asbru: time-annotations and cyclical-plans (b)

Modelling time-annotations and, even more, time-annotations within cyclical-plans is neither straightforward nor intuitive, since there are many aspects to model as can be seen in the examples.

To end up with this section, we would also like to mention the fact that there are actions or data which are required but, for some reason, they are not modelled in the MHB model. From this, we could interpret either (1) it was not modelled in MHB because the modeller overlooked or (2) it was not modelled because it was not explicitly mentioned in the original guideline. From (1), we could say that this two-step approach, and as a consequence the usage of an IR language, is really helpful to detect human errors that, otherwise, would have been detected in more formal stages which is more difficult. From (2), we could ascertain that there is a lack of information in the written guideline, therefore, this additional effort also helps to detect flaws in the guideline, again in early stages.

6 Conclusions

Our aim was to make a qualitative assessment of the MHB language on both aspects: its usability with regard to the guideline modelling and whether it really provides a good intermediate language towards more formal representations. In this sense, conclusions and problematic issues about Asbru are not so meaningful as for MHB, which has not been too much explored yet.

From our approach we conclude that, although MHB covers mostly all the features of the guideline we have modelled, there are still some aspects on which it can be improved.

On the one hand, the methodological process followed in this practical approach, solves in the first stage most difficulties and problematic points coming from the medical field and from the lack of medical knowledge of the knowledge engineer. Although this approach does not turn into an automatic process, the Asbru formalisation of the guideline seems to become easier using MHB, as shown in our experiment. Just before the Asbru modelling, we are provided, by the MHB model, with a series of useful resources such as a hierarchy of plans and a list of data items. Consequently, using this pre-processed information obtained from a unique additional step, formal modelling is eased by reducing effort and time resources.

The ongoing work is (a) to demonstrate that MHB is a good IR language towards other guideline representation languages, (b) to add other aspects not covered by MHB and, (c) to define a methodology for MHB modellers and also Asbru modellers to work in a systematic way in order to obtain better results in less time.

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