# Using FBM, DMN and BPMN to Analyse and Improve Medical Guidelines

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**Abstract.** To improve the quality of health care in the Netherlands, medical guidelines are developed. These guidelines describe recommendations for medical specialists based on scientific research, complemented with expertise and experience of medical specialists. Such guidelines are described in texts of sometimes more than 100 pages. A hospital develops its own guidelines based on this national guideline.

In a project at an academic hospital in the Netherlands, such a guideline was analyzed. The analysis covered a conceptual data model, a decision model and process model and all integration between these different models using FBM, DMN and BPMN, methodically orchestrated by cogNIAM.

From this analysis, the local guideline was made more understandable by removing redundant information, replacing ambiguous definitions with unambiguous ones and resolving detected flaws and inconsistencies. The result of the analysis was also used to develop a software prototype that helps medical specialists in following the guidelines and improving them based on user data.

**Keywords:** Fact Based Modeling (FBM) · Medical guidelines · Decision Model and Notation (DMN) · Business Process Model and Notation (BPMN) · cogNIAM · Cognitatie

## 1 Introduction

In the medical health care in the Netherlands, guidelines for medical professionals are developed. Such a guideline is based on scientific research, complemented with the expertise of medical specialists. Such a guideline is not a purpose on its own, it is meant to help in determining which actions should be performed in what order. The goal of this in general is to improve the health care. The guidelines are not compulsory regulations, but they contain explicit evidence-based recommendations.

The guidelines are described for the "average" patient; therefore, actual practice is often more complex. For this reason, it is permitted to deviate from such a guideline. Reasons to deviate should then be described in the health care file of the specific patient.

The guidelines involved often contain a large volume of text. Furthermore, many hospitals use the guideline as a basis to develop their own in-house guidelines. Guidelines sometimes prove to be ineffective as a tool to improve healthcare. They can be difficult to understand because of redundancy of information in the guideline, the


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use of ambiguous definitions and coverage of possible situations. And of course, because they are currently all text, it is often not possible to easily determine the course of action for a particular situation without reading and understanding a large part of the guideline.

In a project in cooperation with an academic hospital in the Netherlands, such a hospitals guideline was analyzed using Fact Based Modelling (FBM) [6], Business Process Model and Notation (BPMN) [1] and Decision Model and Notation [5]. FBM, BPMN and DMN focus on different aspects of the guidelines. In accordance with the way of thinking of the cogNIAM methodology [3], these different aspects are modelled in coherence and integrated into a singular knowledge model for a specific guideline. The result of the analysis is used to make the hospital's guideline more understandable. As a model will not contain redundant information, it was possible to remove this information from the guideline. For example, multiple conditions were provided to determine which action should be performed, but the result was only dependent on a subset of these conditions (the other conditions did not affect the result of the decision). Also the definitions of terms were improved by removing ambiguities in these definitions.

Another result harvested from the models, is a logical base for a software prototype, which in the future could be used to assist medical specialists in following the guidelines with more predictability and with less time/effort. Further improvements could result from using the prototype (or its production equivalent) and the resulting patient outcomes, as user data from the prototype will be available easily.

The way of working for this project is described in more detail in Sect. 2. Section 3 will explain this way of working further by using an example. The guideline selected for this example is not the local guideline, as this was not allowed due to confidentiality stipulations. Therefore the example is described using the national guideline, which can publically by downloaded at the "Richtlijnendatabase" [8]. Section 4 describes how the analysis was used to generate and use the prototype.

## 2 Way of Working for Medical Guidelines

The way of working is divided in several steps. Of course, starting point is the medical guideline. Additionally, interviews with medical specialists were performed to challenge and verify the guidelines. So the first step consist of gathering information from documents and interviews. All documents are added to Cognitatie [4], a document based analysis platform, in which annotations are used to collect parts of texts of one or more documents. These specific pieces of text are linked together as a collection of available texts for a specific purpose and can also be classified using a self-defined classification scheme. Relevant concepts are extracted from the text and, where necessary, are related to each other. In this way, all relevant parts of the guideline for a specific purpose are collected, but also a first analysis of the necessary concepts and the definitions in the guideline and other documents is performed.

This result is then analyzed in more detail and formalized into models. The resulting models describe different aspects of the knowledge in the guideline. Procedural information will be used to specify a process model. Definitions are captured in the semantics of an FBM model. The decisions rules which describe on basis of what conditions a specific result or action is given, are specified using DMN. But these rules need input, this input must also be described in the FBM model. And of course the data that is input of the DMN and BPMN model is a coherent set of facts, therefore described in fact types with all necessary constraints to have a consistent set of facts.

So the different models used (FBM, DMN BPMN) describe exactly the kind of information they were tailored for, but also complete integration between these models is part of the knowledge model and overall repository. In cogNIAM this aspect is visualized using the cogNIAM knowledge molecule (Fig. 1).

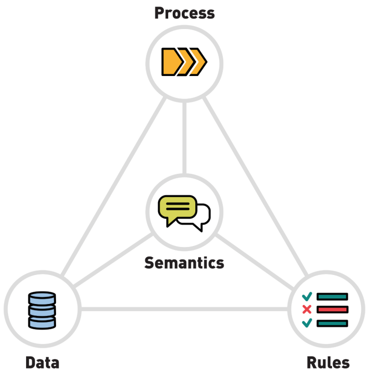



**Fig. 1.** CogNIAM molecule

When analyzing the document and specifying the different models and their integration, a lot of questions arise for the analyst. It is often necessary to involve domain experts (various medical staff) to answers these questions. The type of questions will vary from handling ambiguity in used terms, to undocumented (or unknown) results for a combination of conditions in a decision table, which can either lead to a new rule in the model or provide an "exit point" from the model signifying that a scenario is not expressible in formal rules and should be judged by human expertise. To be able to trace every element of the knowledge specification back to its source, all knowledge elements in the different models are linked to the pieces of text on which they are based. Furthermore additional information provided by domain experts is also stored. This will, in the end, provide traceability and verification back to the original document or domain experts. Cognitatie allows for changes in the versions of the documents to be analyzed automatically and the impact on the model is calculated.

Once a version of the knowledge model is logically sufficiently complete, a software prototype is generated from the result. The prototype takes the process model as a starting point and leads the user through the modelled process. If data is involved, this will directly be linked to the data model and semantics. If a process element is a business rule task, this will point to a decision model, which will be executed automatically. The result of such a decision model itself will again be part of the data model as well.

By providing a prototype as soon as possible, fully based on the specifications, domain experts can easily test the knowledge model. Flaws in the prototype will point out flaws in the different models. Such a flaw can be the result of a (human) error when modelling the guideline, or it can point to a flaw in the guideline. This knowledge can thus be used to improve the model and also the guideline.

Summarizing, the way of working consists of three steps, each broken down into smaller steps. The first step is the analysis of the documents, the second step is developing the specifications using different types of models, but fully integrated. The last step is a transformation of the formal model into something that the end user can use (in this case a software prototype and pointers to improve the guideline). Of course, this is an iterative process. Using the prototype will point out improvements for the guidelines and/or models which, since the prototype reads directly from the models, will in turn improve the prototype so it can be directly used to acquire further user feedback. These three steps are displayed in Fig. 2.

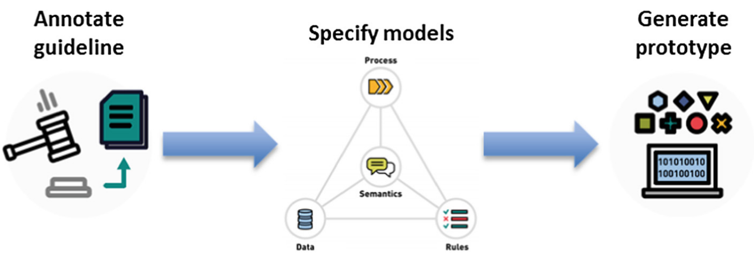



**Fig. 2.** Three main steps of analyzing the medical guideline

## 3 Analysing the Medical Guideline for "Perioperative Policy in Treatment with Vitamin K Antagonists"

A guideline which was subject of the project was the antithrombotic policy [9]. One part of this guideline concerns "Perioperative policy in treatment with vitamin K antagonists". In this chapter, the analysis of a small part of this policy is explained for all steps in the way of working.

### 3.1 Annotating the Texts

The guideline is imported into Cognitatie and annotated to find the different decisions, variables, process steps, etc. The annotation, depending on the chosen classification scheme, can be done by domain experts themselves, by the analysts or combined.

In the guideline, essential parts of the text are annotated. The classification scheme of these annotations is configurable within Cognitatie. In this case, a classification scheme is chosen which holds some (not all) elements of BPMN, DMN and FBM. The text and tables of the guideline must be taken into account as a whole. Because of the textual representation, this is not trivial. Furthermore, in the text references are made to other documents (for example the table for ‘thromboembolic risk’ refers to another document for the $CHA_2DS_2VASc$-score), which makes understanding the guideline even more complex. To resolve this, a composite context is defined in Cognitatie, grouping and linking all text across all documents concerning a particular decision. This not only helps during the analysis to ensure that every necessary piece of text is analysed, it also helps with further analysis and impact analysis in the future (Fig. 3).

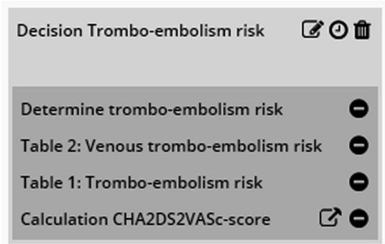
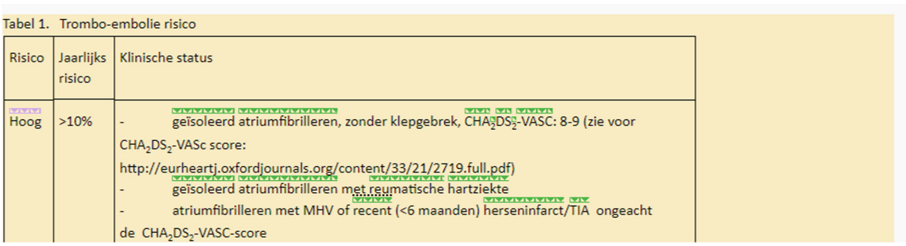



**Fig. 3.** Composite context

After searching and combining the necessary pieces of text, more detailed analysis is performed on the text. Annotating the decision, its rules, activities, (output and input) variables, etc. points out where in the text what part of the further analysis is defined. Coherence (for example which variables are input or output of a particular decision) is added. Also the entity types to which these variables belong are annotated are connected to the variables. If present in the text, relations between the entity types are defined as well (Fig. 4).



Tabel 1. Trombo-embolie risico

| Risico | Jaarlijks risico | Klinische status |
|---|---|---|
| Hoog | >10% | - geïsoleerd atriumfibrilleren, zonder klepgebrek, $CHA_2DS_2$-VASC: 8-9 (zie voor $CHA_2DS_2$-VASc score: http://eurheartj.oxfordjournals.org/content/33/21/2719.full.pdf)<br>- geïsoleerd atriumfibrilleren met reumatische hartziekte<br>- atriumfibrilleren met MHV of recent (<6 maanden) herseninfarct/TIA ongeacht de $CHA_2DS_2$-VASC-score |

**Fig. 4.** Annotated text in Cognitatie

## 3.2 Formalising the Annotations into Formal Models

After annotating the essential pieces of text, the annotations must be formalised into BPMN, DMN and FBM models. This work is performed by the business analyst. The analyst will take the process elements as starting point of his work. All texts, annotations and explanatory notes are taken into account as the analyst defines the process to follow the guideline. Decisions which are not subject to a specialist’s opinion are formalised in the process as a business rule task with a gateway; others as a user task with a gateway. A business rule task calls a decision modelled in DMN or a calculation rule (defined in a formal, more mathematical language). In the case of the guidelines, the business rule tasks call a decision. Trying to draw the process in BPMN leads to questions for the domain experts, because the guideline rarely covers all necessary knowledge to draw the process. Also, all activities use and provide data. This data is described in a FBM model, linking each activity to the actual variables of the fact types used in the activity (read or write).

Furthermore, every used term is defined in the semantic model covering definitions, plurals, abbreviations, synonyms, etc. Again the knowledge of the domain experts is needed and secured in the models. Eventually, the formal model is defined.

Subsequently, the in the business rule task called business rule must be modelled. DMN has two levels for describing the decision; the decision requirements diagram (DRD) and the decision logic. On the level of the decision requirements diagram, it is possible to describe what decisions are involved and what their input is (data and/or other decisions). We define all mentioned input data in the FBM model and it is linked as input data. Additionally, reusability and reducing complexity of decision tables will lead to sub-decisions, which will be input to the decision which the analyst wants to define. For the example of the antithrombotic risk analysis, this will lead to the decision requirements diagram, shown below. In this DRD, only a part of the data input elements is displayed (only for 2 of the decisions) (Fig. 5).

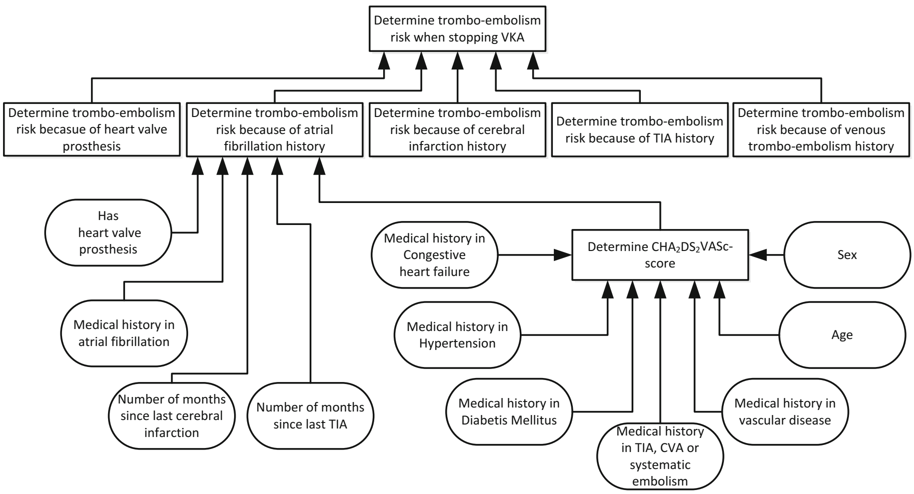



**Fig. 5.** DRD thromboembolism risk

The decisions in the DRD must be described in detail on the level of the decision logic, using a formal language or a decision table. In this example the decision logic is described in decision tables. A lot of the rules necessary for the decision tables are already annotated in Cognitatie. Figure 6 shows the decision table of the decision “Determine thromboembolism risk because of atrial fibrillation history”.

| Determine thromboembolism risk because of atrial fibrillation history | | | | | | |
|---|---|---|---|---|---|---|
| F | History Atrial Fibrillation | $CHA_2DS_2$ VASc score | Heart valve prosthesis | Months since last TIA | Months since last cerebral infarction | Thrombo-embolism risk because of AF |
| 1 | True | >= 8 | - | - | - | High |
| 3 | True | - | True | - | - | High |
| 4 | True | - | - | <6 | - | High |
| 5 | True | - | - | - | <6 | High |
| 6 | True | < 8 | - | - | - | Low |
| 7 | False | - | - | - | - | Low |
| 8 | - | - | - | - | - | Undefined |

**Fig. 6.** Decision table thromboembolism risk because of AF history

As the Business Rule Manifesto [2] states:

"Rules build on facts, and facts build on concepts as expressed by terms."

Therefore all input and output of the decision must be expressed in concepts. In cogNIAM this is handled by having a conceptual data model (FBM-model). Not only are the concepts defined, also all relationships between these concepts are defined as fact types. Furthermore, all data going in and coming out of the process is described in the conceptual data model. This conceptual data model also covers all semantics, such as concept definitions. A part of the conceptual data model for the decision of Fig. 6 is shown in Fig. 7. The FBM model is presented like described in [7].

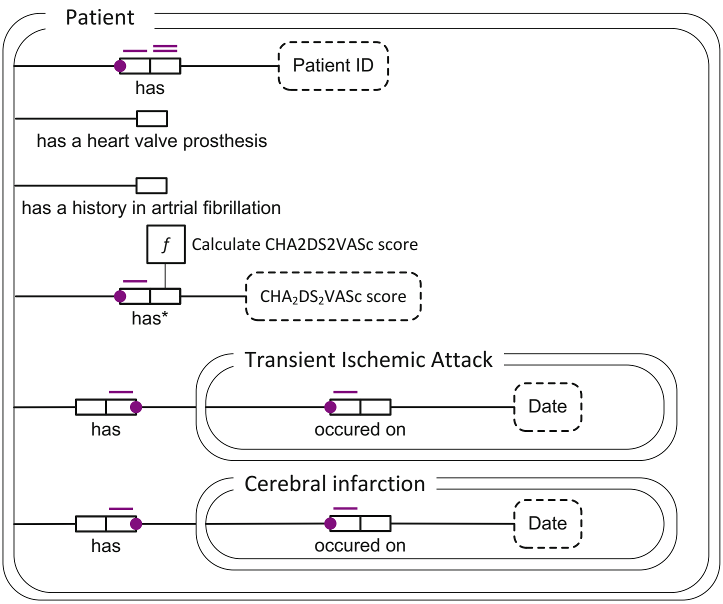



**Fig. 7.** Part of conceptual data model

Between the conceptual data model and the decision table, boxed expressions define what data input is linked to what element in the data model. These boxed expressions can also contain calculation rules, for example calculating the number of months since the last TIA from the dates in the conceptual data model.

## 4 Prototyping

After finishing the first version of all the different models (including the integration between them) a prototype is generated. This prototype is used to ‘live through’ the defined process, using the BPMN-process, DMN-decision and FBM-data model as a logical blueprint. For the decision above this will lead to the following screens in the prototype (Figs. 8 and 9).

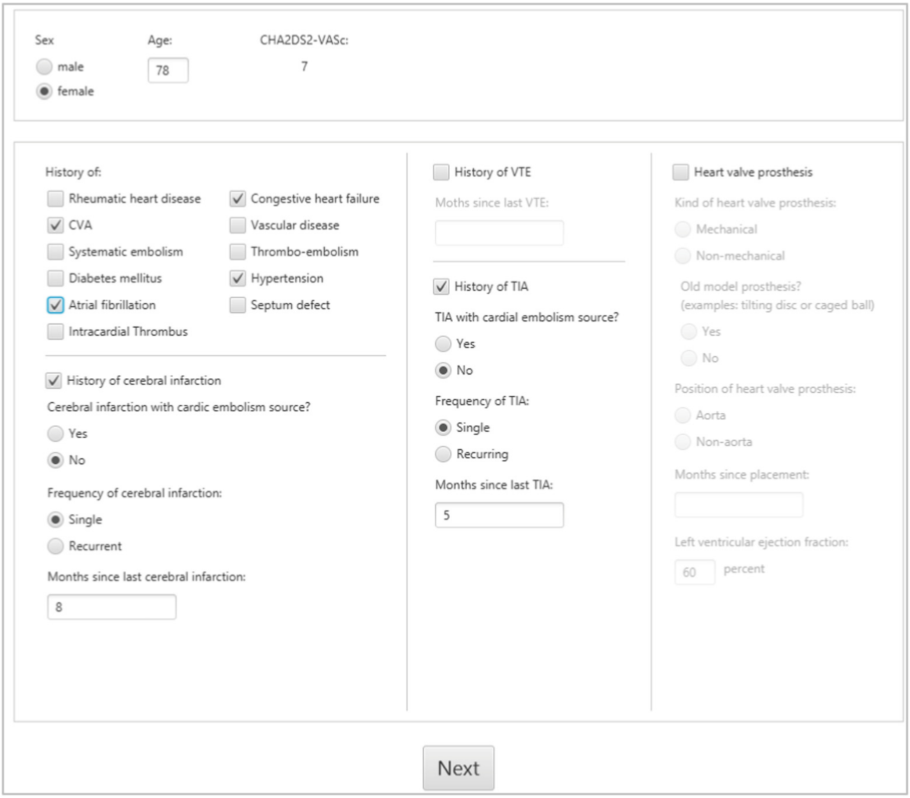



**Fig. 8.** Example of prototype input screen


**Fig. 9.** Example of prototype output screen

This will then again lead to new information as the domain expert will see the impact of the models and can test the defined process and rules. Since the prototype utilizes the integrated data model directly, a new version based on a model enhanced according to feedback from the domain experts is easily generated.

## 5 Summary

Together with medical experts of an academic hospital in the Netherlands, medical guidelines, expressed in documents, are analyzed and defined in process, data and rule models in the standards of BPMN, DMN and FBM.

The guidelines are analyzed in three main steps. First the guideline documents are analyzed. Essential pieces of text are annotated and grouped. Within such a text part, all elements which are needed in one (or more) of the models are annotated and classified. The result of this step is taken as input for defining the conceptual models. A process is modeled in BPMN. All decisions within these processes, which are made on basis of actual facts are described in DMN. And all data structures of the facts used in the process or rule models, including all semantics, are modeled using FBM. Furthermore the integration between these models is defined as well, using the cogNIAM methodology. This leads to a knowledge model, covering all aspects and their integration. The result is a coherent model, without ambiguity in used terms. Also when creating the models, uncovered situations or inconsistency between different parts of a guideline are discovered. In this way, the guideline can be improved.

Finally, a prototype is generated from the created knowledge models, which gives the medical experts more insight in the models created. This helps to iteratively improve the models and from there on the guideline.

The analysis in Cognitatie has another advantage. Changes of the guidelines will be visible in the versions of the documents, pointing out directly where models should be changed. This leads to an efficient and flexible way of handling changes in these documents.

This project proved that using FBM, DMN and BPMN in health care is also a good way of further improving the work done. Of course, the expertise had to come from the domain expert. But the models not only helped to improve the guidelines, it also helped these medical experts in understanding the guidelines better. A more mature piece of model-based software (which in contrast to the prototype meets a pre-defined set of non-functional requirements in addition to the functional requirements) could in the future assist the medical experts in their decisions where and how to follow these guidelines.

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