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FHIR2BPMN: Delivering Actionable Knowledge by Transforming Between Clinical Pathways and Executable Models

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Abstract. Healthcare processes have many particularities captured and described within standards for medical information exchange such as HL7 FHIR. BPMN is a widely used standard to create readily understandable processes models. We show an approach to integrate both these standards via an automated transformation mechanism. This will allow us to use the various tools available for BPMN to visualize and automate processes in the healthcare domain. In the future we plan to extend this approach to enable mining and analyzing executed processes.

Keywords. Clinical Guidelines, Model Transformation, HL7 FHIR

1. Introduction

Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR)[2] is a well-established standard in healthcare, which is used to support the exchange of data between information systems [1]. FHIR describes data formats as well as resources and provides interfaces for exchanging them.

One of these resources is the PlanDefinition, which allows the description of clinical artifacts. The FHIR R4 specification describes it as follows [2]:

> "This resource allows for the definition of various types of plans as a sharable, consumable, and executable artifact. The resource is general enough to support the description of a broad range of clinical artifacts such as clinical decision support rules, order sets and protocols." [2]

Business Process Model and Notation 2.0 (BPMN) on the other hand is a well-established standard by the Object Management Group (OMG). It is widely used in the

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community and there is a lot of tooling available for modelling, simulating, and executing business processes. The use of BPMN as well as CMMN (Case Management Model and Notation) and DMN (Decision Model and Notation) for healthcare is described in the *Field Guide to Shareable Clinical Pathways* [4] and summed up in the term *BPM+*.

We provide an approach to make BPMN and FHIR interoperable. Based on this interchange between two well-established standards, this provides a basis to define, document, and mine processes in healthcare. We showcase this by manually modelling clinical guidelines in the FHIR PlanDefinition resources, which in turn are then automatically transformed using our presented approach. The results are then compared with a BPMN tool and validated by domain experts.

1.1. Problem Statement

Evidence based Clinical Pathways (CPs) are an important factor in modern healthcare. Typically presented in the form of narrative text, they aim to provide knowledge for healthcare professionals, guide the allocation of resources, reduce the risk of liability for negligence in the duty of care, and enable the assessment and assurance of quality in healthcare [3]. Note that the terms *Clinical Pathways*, *Clinical Guidelines*, or *Clinical Practice Guidelines* are often used interchangeably in literature.

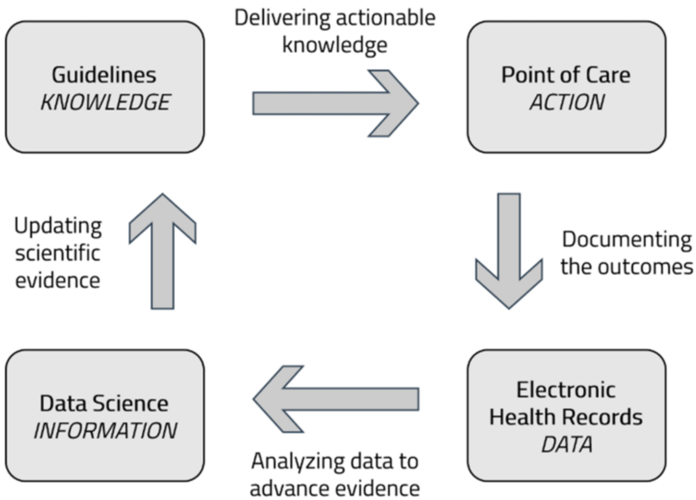

Figure 1. The data lifecycle with clinical guidelines as representation of knowledge (from [6]).

Due to their narrative nature, CPs are open to large variations of interpretation. To be viable as a basis for, e.g., computer-based workflow orchestration, decision support systems, or automated compliance checks, these CPs must be made explicit, including formal, repeatable semantics [4].

Figure 1 shows the basic idea how CPs/Guidelines as representations of scientific evidence can be used to deliver actionable knowledge at the point of care. Of course, there are attempts to tackle the challenge of computable CPs. Computerized Clinical Decision Support Systems (CDSS) are among the most successful solutions for this challenge [5]. Although decision support systems in medicine have been developed for the better part of three decades, they mostly “exist as cumbersome stand-alone systems, or exist in a system that cannot communicate effectively with other systems” [5].

Moreover, the knowledge embedded in these systems is often described using formal programming languages, not readily understandable by healthcare professionals and business analysts [4].

BPMN provides the means to model complex clinical processes, showing who does what, where and in what sequence [1]. It distinguishes between the flow of activities of single actors and the flow of messages and information between them. It enables visualization and has a formal notation where models can be executed by a workflow engine. However, it provides only a very generic notion of activities, not considering the specificities of healthcare. While BPMN is exchangeable via the XML format, the standard lacks mechanisms for lifecycle-management, i.e., storing, versioning or updating the model. It also allows for *dialects*, i.e., different ways of modelling the same process, thus making interoperability hard.

HL7 FHIR, on the other hand, comes with a rich information model for clinical data and mechanisms for versioning, provenance, access control, and messaging, among others. Certain resources are even designed to store CPs or elements of clinical workflows [6], i.e., the PlanDefinition resource. However, FHIR does not define how to visualize resources and while they can contain the information necessary for execution, resources do not define how to make them executable.

1.2. Proposed Solution

We aim to make computable CPs both, interoperable *and* readily understandable. We do not present a new standard to combine all features of BPMN and HL7 FHIR but develop an automated transformation approach between these formats. This can be seen as a basis for better computable CPs.

Since both models, the HL7 FHIR Plan Definition and the BPMN model, can be represented as graphs, we can define rules on how to map between the various elements in the corresponding models and use a graph transformation framework (GTF) [7] to implement and apply these rulesets.

We enable HL7 FHIR's capabilities to manage and transport clinical information in a structured, standardized way and we enable BPMN's potential to visualize models and to fuel them into workflow engines.

2. Method

Figure 2 depicts the top-level transformation approach. Our approach relies on the fact, that both the BPMN Metamodel and the FHIR Resource specification are mappable to a Graph-structure. This in turn allows us to transform the BPMN Model, which is defined by the BPMN Metamodel, and the FHIR workflow resource specification (PlanDefinition), which is defined by the FHIR Resource specification (Structure-Definition), into an interim graph structure, which conforms to the graph model.

This interim structure reduces the complexity of the overall transformation, as it neither relies on input nor output models. The interim graph structure is defined by the respective transformation implementation in the GTF. The transformation is then defined by the set of rules that allow to transform from and to the interim graph.

Finally, on the instance level, we see the BPMN Clinical Pathway, which conforms to the BPMN Model as well as the FHIR Clinical Pathway, which in turn conforms to the FHIR Workflow resources. By applying the previously defined rule sets, a transformation between these instances is enabled.

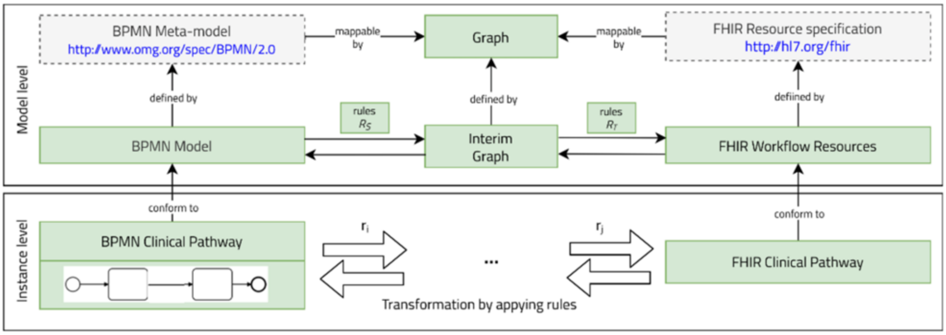

Figure 2. The basic transformation architecture based on an interim graph.

The main contribution of this work is the combination of HL7 FHIR with BPMN, enabling definition and visualization of processes, while also being able to consider the intricacies of healthcare systems. This is enabled by our transformation approach. It identifies patterns for the various concepts and defines transformation rules for each pattern. Both representations offer various concepts that can be used to define processes.

3. Results and Discussion

To be able to create transformation rules, it is necessary to identify patterns in both model domains that can be matched. We focused on six core concepts, namely (1) sequence flow, (2) exclusive split and (3) parallel split, (4) data flow, (5) triggers and (6) actors or participants. In this section, we will show the mappings for one of the six core concepts defined above, (1) the sequence flow.

All transformation patterns developed in this work can be found on the GitHub repository[3] also referenced in [8].

Table 1. Representation of sequence flow in FHIR PlanDefinition and BPMN [8].

HL7 FHIR PlanDefinition	**BPMN**
<action> <id value='t1'/> <title value='Task 1'/> <relatedAction> <actionId value='t2'/> <relationship value='before-start'/> </relatedAction> </action> <action> <id value='t2'/> <title value='Task 2'/> </action>	<userTask name="Task 1" id="t1"> <outgoing>sf_t1_t2</outgoing> </userTask> <userTask name="Task 2" id="t2"> <incoming>sf_t1_t2</incoming> </userTask> <sequenceFlow sourceRef="t1" targetRef="t2" id="sf_t1_t2"/>

[3] https://fhooeaist.github.io/MSBPMN/transformation.html

In BPMN, the sequence flow is modeled by defining a *sequenceFlow* element that references the two *task* objects it connects. In the FHIR PlanDefinition we can achieve this by adding a nested *relatedAction* element into one of the two actions and by defining the ID of the other action as well as the relationship type (see Table 1).

The remaining concepts (2)-(6) require the interaction of the tasks with other elements, such as gateways, data elements, triggers, or actors. In BPMN this is modelled by defining these elements on the top-level structure and having linking elements between these elements and the tasks, building a flat hierarchy inside the model. For the FHIR PlanDefinition this is modelled differently, with elements as nested structures inside the tasks. Gateways, for example, are modelled by nesting tasks inside other tasks and specifying *groupingBehaviour* and *selectionBehaviour* for the parent element to define the relationships [2]. This leads to potentially deep, tree-like hierarchies. These structures need no separate linking elements, but due to their hierarchical structure they come with limitations, e.g., regarding loops and jumps.

We tested the approach on the basic patterns listed in Section 2 and on more complex CPs. The resulting diagrams including the initial FHIR PlanDefinition resources can be found in high resolution in the GitHub repository[4]. Figure 3 shows an automatically generated BPMN model based on the transformation result of the Austrian Federal Quality Guideline for Preoperative Diagnostics (BQLL PRÄOP) [9]. All subprocesses were expanded.

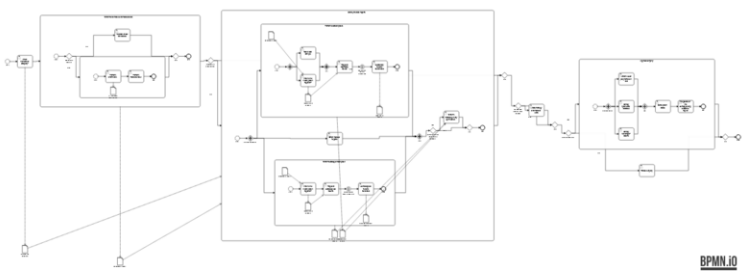

Figure 3. BPMN representation of the Federal Quality Guideline for Preoperative Diagnostics [9].

Preoperative diagnostics is used for the early detection of risks that may arise during and after surgery. It also serves to assess the basic fitness of patients for surgery. The guideline includes steps such as completing a structured questionnaire for medical history, performing cardiopulmonary testing, or determining various standardized scores in advance of deciding whether to perform a surgery [9].

To validate our transformation approach, we first created a FHIR PlanDefinition resource based on the narrative description in [9]. In the next step we automatically applied our transformation rules to generate a BPMN representation. The resulting XML file was then rendered (Figure 3) and compared to the narrative CP by domain experts.

The main finding was that the general flow (i.e., key activities and their sequence) was clearly identifiable and correctly represented in the model. However, some shortcomings of our approach were also identified: (A) a lack of formalization of decision tables for XOR gateways, (B) certain meaningful modeling elements that BPMN would provide, e.g., Swimlanes, were not used, and (C) loops, e.g., to repeat uncertain laboratory tests, are currently not possible due to the limitations of the hierarchical model described in Section 3.

[4] https://fhooeaist.github.io/MSBPMN/fhir2bpmn.html

To tackle (A) we plan to use DMN to formalize the decision points. However, we must determine whether the approach is compatible with the formal logic currently built into the HL7 FHIR resources described in [6]. (B) requires further research and coordination with the FHIR Workflow project as to how these elements can be modeled with the existing FHIR resources. For (C), we discuss the following two approaches: (C1) flatten the hierarchy in the PlanDefinition resource and use a referencing mechanism instead, or (C2) add the referencing mechanism despite the hierarchical base structure. We need to further investigate the consequences of these approaches and discuss them within the FHIR Workflow community.

4. Outlook

While the transformation still has its limitations, applying it to existing CPs, already represented as PlanDefinition resources, could be useful to enable the broader tooling of the BPMN domain. The understanding of the structure and semantics of the building blocks of healthcare workflows will also be helpful to provide inputs for the further development of the PlanDefinition resource, making it more suitable to represent CPs.

We will continue our work on the analysis of standards-based event logs by the means of process mining [10]. The transformation patterns and the interplay of FHIR workflow resources are also relevant for the analysis of FHIR audit record repositories.

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