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Interoperability Improvement of Mobile Patient Survey (MoPat) Implementing Fast Health Interoperability Resources (FHIR)

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Abstract. Despite the advances in health information technology and the increasing usage of electronic systems, syntactic and semantic interoperability between different health information systems remains challenging. An emerging standard to tackle interoperability issues is HL7 FHIR, which uses modern web technologies for communication like Representational State Transfer. The electronic patient reported outcome system Mobile Patient Survey (MoPat) was adapted to support metadata import and clinical data export using HL7 FHIR. Thereby, the data models of HL7 FHIR and MoPat were compared and the existing import and export functions of MoPat were extended to support HL7 FHIR. A test protocol including eight test datasets to proof functioning of the new features was successfully conducted. In the near future, a real time searching toolbar of FHIR metadata resources will be integrated within MoPat. MoPat FHIR import and export functions are ready to be used in a clinical setting in combination with a FHIR compliant clinical data server.

Keywords. Health Information Systems, Health Information Interoperability, Patient Reported Outcome Measures

1. Introduction

The advances in health information technology result in an increasing usage of electronic documentation systems like electronic health records (EHR) and electronic data capture (EDC) systems. These systems are nowadays not only implemented for a single purpose, but facilitate data sharing and reuse in other systems such as quality management or research. To exchange data with other systems syntactic and semantic interoperability is key. Politicians have also raised concern about this important issue: legislation like the 'HITECH Act' in the US in 2009 [1] and programs like the German Medical Informatics Initiative in 2015 [2] (among others) were adopted to foster health data exchange and reuse.

The Fast Health Interoperability Resources (FHIR) from Health Level-7 (HL7) is an emerging standard to facilitate healthcare related data exchange. HL7 FHIR® was developed to exploit the strengths of its predecessors (HL7 v2 and v3), but avoid their shortcomings, e.g. support of modern web service technologies. To do so, FHIR resources define distinct identifiable entities, which are openly developed. On top of these entities, FHIR defines an application programming interface using

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Representational State Transfer to access data stored within an FHIR server [3]. As an example of the forthcoming importance of HL7 FHIR, all funded projects of the German Medical Informatics Initiative (DIFUTURE [4], HiGHmed [5], MIRACUM [6] and SMITH [7]) consider using FHIR to exchange health related data.

The Mobile Patient Survey (MoPat) is a web-based Patient Reported Outcome (PRO) System developed in Java [8]. MoPat includes a template-based export mechanism that facilitates data exchange using HL7 v2 for the communication with EHR systems and the Operational Data Model format, which can be imported by several EDC systems [9].

The aim of this research is to implement and test a FHIR import mechanism and extend the template-based export mechanism of MoPat with the FHIR format, enabling data transfer to several endpoint systems such as the medical data integration centres within the German Medical Informatics Initiative.

2. Methods

Initially, MoPat questionnaire data models and the FHIR questionnaire resource were compared using Unified Modeling Language class diagrams. All relevant FHIR attributes were mapped to the corresponding attributes in MoPat. Based on this mapping, import and export mechanisms were developed within MoPat using Java programming language and the open source HAPI FHIR library[2] enabling communication with FHIR compliant servers. HAPI FHIR also provides an open source implementation of a FHIR test server, which was used for testing purposes.

To reach high test coverage, a test protocol including various test datasets was designed. Eight datasets were defined to test the import mechanism, each one including a FHIR questionnaire. The first test questionnaire contains all mapped question types and different language extensions to test the common use case as intended by the FHIR questionnaire resource. Seven other questionnaires were defined to test different corner cases and additionally supported FHIR extensions that are listed on the FHIR Extension Registry[3] to enable reuse.

To automate the testing of and proof the functioning of the clinical data export, Selenium[4] test scripts were implemented. These scripts completed a survey using the MoPat web interface. Afterwards, the correctness of the transmitted data was validated using the web interface of the HAPI FHIR test server.

3. Results

Figure 1 represents the mapping of the FHIR structure in extracts on the left side, linked via arrows to the corresponding MoPat database entities. The relevant metadata in FHIR is the questionnaire resource containing the element item, which represents the data model of a single question. The item itself includes an attribute called type, which represents the type of the question as QuestionnaireItemType. Some of the mappings to the MoPat question types such as display, date, Boolean, choice, open-choice, string and

[2] http://hapifhir.io/
[3] https://www.hl7.org/fhir/extensibility-registry.html
[4] https://www.seleniumhq.org/

text are straightforward. However, numerical questions have different display options in MoPat, so the mapping of the FHIR types integer and decimal has to be split. If the amount of possible answers for integer questions is limited to no more than ten, the NUMBER_CHECKBOX type is chosen and by default, checkboxes with numbers on it are displayed. Following this approach, for decimal questions the SLIDER type is chosen, which displays a slider enabling the selection of the integer answers limited to not more than 200. All other cases are mapped to the NUMBER_INPUT type in MoPat, which allows the manual entry of numerical values.

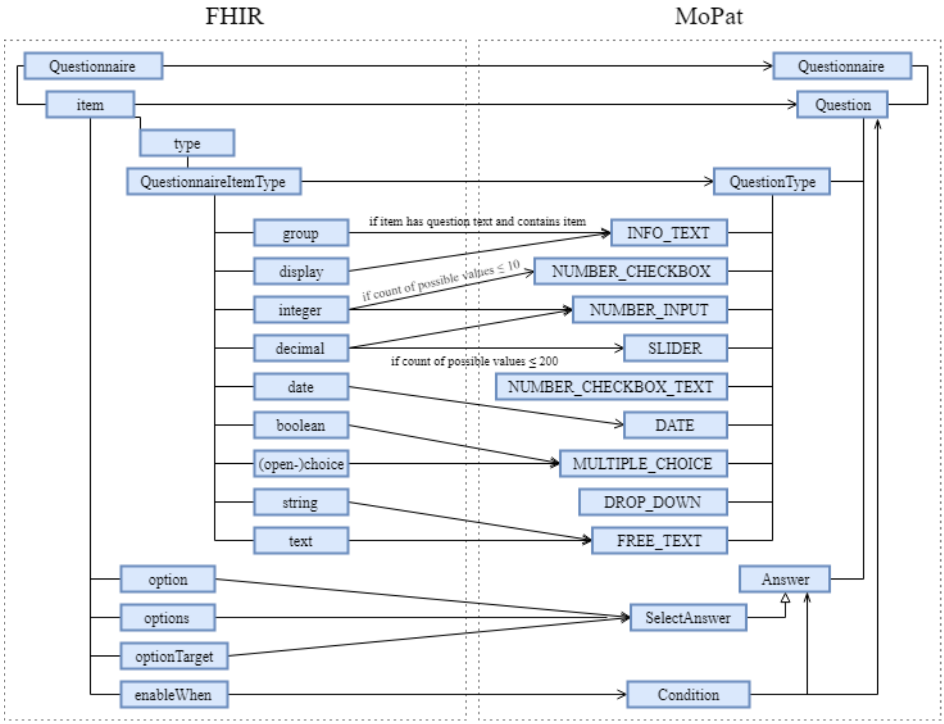

Figure 1. Mapping results of the FHIR questionnaire resource mapped to the MoPat Questionnaire database model. Only mapped FHIR QuestionnaireItemTypes are shown.

The FHIR question type "choice" needs additional information about selectable options. This information is stored in the "option", "options" and "optionTarget" elements and every option is mapped to a SelectAnswer within MoPat. For Boolean questions, two SelectAnswers will be created using yes and no as possible answers.

Both FHIR Questionnaire items and MoPat questions can be activated and deactivated by selecting answers in previous questions. The condition for the activation or deactivation is stored in the FHIR attribute "enableWhen" and can be mapped to the MoPat Condition object.

The existing import mechanism within MoPat was expanded to accept FHIR questionnaire resources in Extensible Markup Language (XML) format and Uniform Resource Locators (URLs) pointing to questionnaire resources stored on a FHIR server. To enable clinical data export using the FHIR resource "QuestionnaireResponse", the ability to upload FHIR Questionnaire resources as export templates was also implemented.

Lastly, an exporter was implemented to write the given answers into the uploaded export template using the configured export mappings. MoPat can be configured to export this filled export file to multiple FHIR servers and to write it on hard disk for backup purposes.

The import mechanism was tested by importing eight different datasets each comprising a single questionnaire resource. The first data set contains at least one item for each mapped QuestionnaireItemType as shown in Figure 1. This set includes the basic use cases for each type. For all those QuestionnaireItemTypes, which involve extensions that are also supported by MoPat, data sets were constructed that contain multiple test cases using these extensions.

The following extensions were implemented and tested: questionnaire-ordinalValue; questionnaire-minOccurs; questionnaire-maxOccurs; minValue and maxValue.

The extension ordinalValue was tested with the item type “choice”. This extension enables every option in a choice question to store a decimal value for scoring purposes. Both extensions minOccurs and maxOccurs also apply to the “choice” type defining the minimum and maximum numbers of answers that can be given. MoPat supports as well storing of score values within SelectAnswers and the limitation of selectable answers, so these extensions can be imported without any problems. Finally, the extensions minValue and maxValue can store the inclusive lower and upper bound on the range of allowed values for answering the associated question. These restrictions can be applied to the imported question types integer, decimal and date. As shown in Figure 1, the import of these data types varies depending on the values stored within these extensions. Therefore, data sets were developed including integer items with ten possible values (+/-1) and decimal items with 200 possible values (+/-1). All developed test data sets were imported correctly and answered questionnaires were exported properly to the FHIR test server.

4. Discussion

The implementation of MoPat was extended by an import mechanism for questionnaires in HL7 FHIR format and an exporter that enables clinical data export to FHIR compliant servers.

The comparison of the data structures of MoPat questionnaire and FHIR questionnaire resource showed that the FHIR format supplies a wider range of question types than MoPat. Thus, it cannot be guaranteed that a questionnaire in FHIR format can be imported completely as some data could be lost. However, most of the question types can be imported. To inform the user about such problems a result page is displayed after finishing the import were information about not imported or modified metadata is shown. Accordingly, the user can react upon these remarks correcting the import file and import again or edit the imported questionnaire within MoPat.

A different method could have been to profile the questionnaire resource using a StructureDefinition[5] resource. This enables systems like MoPat to restrict existing resources and communicate the supported or expected extensions. Since MoPat is not a FHIR-Server itself, it is not intended to support an upload of questionnaires by an application programming interface (API) and the importing mechanism should mainly

[5] http://hl7.org/fhir/2018May/structuredefinition.html

be used by medical experts. Thus, only a human-readable description of the constraints and supported extensions is given on the import page. If import via API is integrated within MoPat, also a capability statement will be included in order to communicate the implemented StructureDefinition

Currently, the upload of metadata in FHIR format is restricted to questionnaire resources in XML format. However, the HAPI FHIR library is able to accept questionnaires in JSON format and MoPat is going to include this feature soon. Furthermore, the importer enables the import of questionnaire resources via Uniform RL from remote applications that implement the FHIR RESTful application programming interface (API). The import of resources via REST API could be enriched by a search function of questionnaire resources that are located on FHIR conform servers. It could be combined with a RESTful web service that allows to integrate questionnaire resources from the Portal of Medical Data Models [10].

Another approach to collect PROs utilizing FHIR was introduced by Pfiffner et al. in 2016. A framework was built to enable the storage of FHIR compliant PRO data in an i2b2 database collected by ResearchKit apps. It also included consent management and encryption of communicated health data. Unfortunately, the website of the project seems to be no longer available.[11]

Since, the testing of the import and export mechanisms were only under laboratory conditions, the newly developed functions should be tested in a real study using a FHIR compliant server for storing the clinical data of the study participants.

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