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HL7 FHIR: Ontological Reinterpretation of Medication Resources

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Abstract. "A solid ontology-based analysis with a rigorous formal mapping for correctness" is one of the ten reasons why the HL7 standard *Fast Healthcare Interoperability Resources* (FHIR) is advertised to be better than other standards for EHR interoperability. In this paper, we aim at contributing to this formal analysis by proposing an RDF representation of a subset of FHIR resources based on a highly constrained top-level ontology and guided by the use of a set of Content Ontology Design Patterns (Content ODPs) for representing clinical information. We exemplify this by reinterpreting FHIR medication resources. Although a manual task now, we foresee a possible automatic translation by using RDF shapes.

Keywords. FHIR, RDF, Ontology, Semantic Interoperability, EHR

1. Introduction

The new HL7 standard *Fast Healthcare Interoperability Resources* (FHIR) [1] is a recent approach to semantic interoperability of electronic health records (EHRs). FHIR is propagated as an open standard with a high alignment with the Semantic Web [2], representing a new EHR modelling paradigm based on interoperable building blocks named *resources* [3]. FIHR resources are small data models that define a set of properties describing certain domain aspects. Currently, there are around a hundred of them, classified into six categories, and uniquely identified with a URI. Examples are *Patient*, *Practitioner*, *Medication order,* or *Observation.* FHIR resources can be serialized in JSON, XML and recently in RDF, still as a draft representation. Although FHIR was not designed with Semantic Web and RDF in mind, FHIR resources and links between them align well. The Yosemite project [5] has recently proposed RDF as universal language for healthcare data exchange. In this line, HL7 in collaboration with W3C [5] proposed an RDF representation for FHIR aiming at improving interoperability with other standards. Due to the nature of RDF and the structure of FHIR, its RDF representation focuses on representing the structure of a resource rather than the content [6]. FHIR RDF instances conform to the FHIR ontology, which introduces classes and properties. However, it is not yet connected to any formal top-level ontology such as BFO [7], BTL2 [8] or OGMS [9], and therefore ontologically shallow [10].

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Top-level ontologies provide domain-independent categories, relations and axioms (e.g. categories like *Process*, *Material entity*, *Quality*, etc.) in order to standardize the ontology creation by heavily constraining it, according to a rigorous ontological commitment. Therefore, building the FHIR ontology under a top-level ontology should contribute to improve its semantic interoperability with other representations.

Here we suggest the use of the top-level ontology BioTopLite 2 (BTL2) as a compromise between degree of formalization (i.e. constraining axioms) and complexity, contributing to a quick learning curve. BTL2 bridges with other ontologies such as BFO, and SNOMED CT content has started to be harmonized with basic top-level classes and relations of BTL2 [11]. Despite the benefits of top-level ontologies [11], their use is not trivial and requires of some effort. The EU project SemanticHealthNet [12] proposed content ontology design patterns (Content ODPs) to ease the modelling of clinical information under BTL2 [13]. Content ODPs provide templates for recurrent modelling content, underpinned by formal ontologies [14].

In the following we apply a set of Content ODPs to reinterpret FHIR medication resources using BTL2 and comment on the benefits of the proposed representation with a query exemplar. Finally, we discuss open issues and future work.

2. Methods

The main **FHIR Medication Resources** are shown in Figure 1 and Table 1.

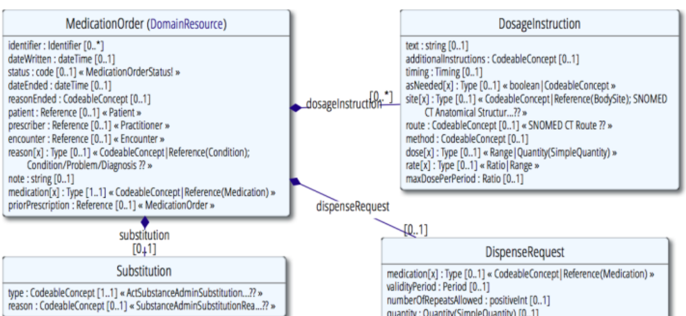

Figure 1. UML diagram of the *MedicationOrder* resource, to which the resources *DosageInstruction*, *DispenseRequest* and *Substitution* are linked. Values with "Reference" also represent FHIR resources

Table 1. Medication related main FHIR resources

Resource name	Resource description
MedicationOrder	An order for both supply of the medication and the instructions for administration of the medicine to a patient
MedicationDispense	Provision of a supply of a medication with the intention that it is subsequently consumed by a patient (usually in response to a prescription).
MedicationAdministration	When a patient actually consumes a medicine, or it is otherwise administered to them

BTL2-based Ontology Framework and Content ODPs. The integration of heterogeneous clinical information is enabled by a formal ontology framework that focuses on representing content instead of content structure, and which supports formal inference [15]. This framework encompasses the ontologies BTL2 (prefix "btl2") and SNOMED CT (prefix "sct"), as common reference point for representing the clinical content. The framework strictly distinguishes between real world content, represented by classes like *Lung cancer*, *Blood pressure*, etc. and information (e.g. *Lab test result*, *Diagnostic statement*, *Drug order* etc.). Information entities are related to real-world entities via the relation **represents**. Content patterns act as templates to represent recurring modelling cases (e.g. Participation, Plans). Table 2 shows the main patterns for reinterpreting FHIR medication-related resources in RDF. Correspondences between OWL and RDF representations are shown in Table 4.

(1) *Plan* ISRESULTOFPROCESS *?Process*
(2) *Plan* HASINFORMATIONPART *?InformationObject*
(3) *Plan* PERFORMSPROCESS *?Process*
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(4) *Process* HASTEMPORALVALUE *?TemporalRegion*
(5) *Process* HASRESULT *?InformationObject*
(6) *Process* HASPARTICIPANT (*?MaterialObject* or *?InformationObject*)
(7) *Process* HASQUALITY *?ValueRegion*
(8) *Process* ISDUETO (*?MaterialObject* or *?InformationObject* or *?Process* or *?ImmaterialObject* or *?Disposition*)
(9) *Process* HAPPENSBEFORE *?Process*
(10) *Process* HAPPENSAFTER *?Process*
(11) *Process* ISINCLUDEDIN (*?MaterialObject* or *?ImmaterialObject*)

Figure 2. RDF triple [16] representation of Planned Process and Clinical Process patterns. RDF predicates (in small caps) correspond to OWL object properties or expressions using BTL2. BTL2 classes are given in Italics. A question mark in an OWL class label represents a variable part within the pattern.

Table 2. Description of main Content ODPs used for describing FHIR medication resources

Content ODP name	Pattern description
Planned Clinical Process	Record entry about the intent to perform some healthcare related process (e.g. request to administer some drug, plan to reach some target body measurement (e.g. weight), request to perform some healthcare service (e.g. check potassium level, etc.)
Clinical Process	Clinical process description (e.g. observation, assessment, history taking, request process, physical examination, etc.)

3. Results

Correspondences between the medication-related resources and the RDF Content ODPs have been manually defined in order to re-interpret the existing FHIR representation based on the proposed ontology framework. Table 3 shows the correspondences between the FHIR resource *MedicationOrder* and the Content ODPs PlannedClinicalProcess and ClinicalProcess. In FHIR, a *MedicationOrder* is an order for both supply of the medication and the instructions for administration of the medicine to a patient. Within the ontology, it is reinterpreted as a plan (information entity) resulting from a prescription process (*MedicationPrescription*), which has as parts supply (*SupplyMedicationOrder*) and administration (*MedicationAdministrationOrder*) orders, information entities that have as realizable *MedicationDispense* and *MedicationAdministration* processes respectively.

In total, we have created 289 classes, 718 logical axioms and 119 object properties within the ontology. The DL expressivity is SIQ(D). Table 4 shows the OWL DL correspondences for the RDF predicates used.

BTL2 allows standardizing the way the ontology is queried, and content ODPs guide the building of the queries. Besides, BTL2 allows querying homogeneously different ontologies (e.g. SNOMED CT + FHIR), previously harmonized, as well as heterogeneous FHIR resources, now semantically related within the ontology. The following query example (Figure 3) detects cases in which although the patient has an allergic intolerance to *sct:Ibuprofen*, it was prescribed to him. Additionally, logical reasoning supports more generic queries e.g. for products that contain ibuprofen.

Table 3. Correspondences between FHIR *MedicationOrder* and the Content ODPs PlannedClinicalProcess and ClinicalProcess. For the classes defined within the corresponding pattern, subclasses are introduced (e.g. *MedicationPrescription* **rdfs:subClassOf** *Process*). Predicates have been renamed for the use case and are equivalent to the ones defined within the corresponding pattern triple. Prefix ("fhir") has been omitted. The number indicates the pattern triple as described in Figure 2.

FHIR Resource	RDF Content ODP based representation
identifier	(2) *MedicationOrder* MEDICATIONORDERIDENTIFIER *PrescriptionOrderID*
dateWritten	(4) *MedicationPrescription* MEDICATIONORDERDATEWRITTEN *PrescriptionDateWritten*
status	(2) *MedicationOrder* MEDICATIONORDERSTATUS *PrescriptionOrderStatus*
dateEnded	(4) *MedicationPrescription* MEDICATIONORDERDATEENDED *PrescriptionDateEnded*
reasonEnded	(2) *MedicationOrder* MEDICATIONORDERREASONENDED *PrescriptionOrderReasonEnded*
patient	(6) *MedicationPrescription* MEDICATIONORDERPATIENT *Patient*
prescriber	(6) *MedicationPrescription* MEDICATIONORDERPRESCRIBER *Practicioner*
encounter	(1) *MedicationOrder* MEDICATIONORDERENCOUNTER *Encounter*
reason	(2) *MedicationOrder* MEDICATIONORDERREASON *PrescriptionOrderReason*
note	(2) *MedicationOrder* MEDICATIONORDERNOTE *PrescriptionOrderNote*
medication	(6) *MedicationAdministration* MEDICATIONORDERMEDICATION *PharmaceuticalProduct*
priorPrescription	(10) *MedicationPrescription* MEDICATIONORDERPRIORPRESCRIPTION *MedicationPrescription*
dosageInstruction	(2) *MedicationOrder* MEDICATIONORDERDOSAGEINSTRUCTION *MedicationAdministrationOrder*
dispenseRequest	(2) *MedicationOrder* MEDICATIONORDERDISPENSEREQUEST *SupplyMedicationOrder*
Substitution	*Not modelled*

Table 4. Examples of correspondence between RDF predicates and their OWL DL representations

RDF Predicate	OWL DL correspondence
MEDICATIONORDERPRESCRIBER	*fhir:MedicationPrescription* and **btl2:hasAgent** some (*fhir:Practicioner* and **btl2:isBearerOf** some *fhir:PrescriberRole*)
MEDICATIONORDERENCOUNTER	*fhir:MedicationOrder* and **btl2:isOutcomeOf** some *fhir:Encounter* and **btl2:isOutcomeOf** max 1 *fhir:Encounter*
MEDICATIONORDERMEDICATION	*fhir:MedicationAdminsitration* and **btl2:hasParticipant** some *fhir:PharmaceuticalProduct* and **btl2:hasParticipant** max 1 *fhir:PharmaceuticalProduct*

```
SELECT ?IbuprofenPrescription ?IbuprofenAllergy
WHERE {
   ?IbuprofenAllergy rdf:type fhir:AllergicIntolerance .
   ?IbuprofenAllergy btl2:hasRealization ?ProcessX .
   ?ProcessX btl2:hasParticipant ?AllergicPatientX .
   ?AllergicPatientX rdf:type Patient .
   ?ProcessX btl2:isCausedBy ?IbuprofenSubstance .
   ?IbuprofenSubstance rdf:type sct:Ibuprofen .
   ?IbuprofenPrescription rdf:type fhir:MedicationOrder .
   ?IbuprofenPrescription btl2:hasPart ?IbuprofenAdministrationOrder .
   ?IbuprofenAdministrationOrder rdf:type fhir:MedicationAdministrationOrder .
   ?IbuprofenAdministrationOrder btl2:hasRealization ?MedicationAdministrationX .
   ?MedicationAdministrationX rdf:type fhir:MedicationAdministration .
   ?MedicationAdministrationX btl2:hasParticipant ?ProductY .
   ?ProductY btl2:hasPart ?IbuprofenSubstance .
   ?IbuprofenPrescription btl2:isOutcomeOf ?EncounterX
   ?EncounterX rdf:type fhir:Encounter .
   ?EncounterX btl2:hasParticipant ?PatientX .}
```

Figure 3. SPARQL query example

4. Discussion and Conclusion

We have proposed to reinterpret FHIR resources by using BTL2 and Content ODPs. Three domain medication resources have been reinterpreted. We describe it for the *MedicationOrder* resource, in RDF and OWL DL and comment on the benefits.

At the moment the translation into the proposed RDF representation is a manual process. We are working on representing Content ODPs using shapes represented in SheX [17] and SHACL [18], in order to automate the translation and perform RDF graph data validation, supporting inference in cases based on both the open and closed world assumption [15].

FHIR resources allow an extension mechanism to add new attributes to the predefined list of resources, which can even modify the meaning of the resource [19] (e.g. not take a medication, as extension of MedicationOrder). A top-level ontology such as BTL2 aims standardizing this process and prevents semantic inconsistencies that risk semantic interoperability by creating silos of non-interoperable information.

Since RDF requires monotonicity (i.e. new assertions cannot invalidate old conclusions), the existing draft FHIR RDF representation focuses on EHR structure instead of content. Representing negation is therefore a critical point (e.g. patient does not have allergy to ibuprofen). For this and other representation issues such as elements ordering several approaches are possible, however out of the scope of this paper.

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