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FHIR Based ContSys Ontology to Enable Continuity of Care Data Interoperability

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Abstract. In the midst of a global pandemic, perspectives on how digital can enhance healthcare service delivery and workflow to address the global crisis is underway. Action plans collating existing digital transformation programs are being scrutinized to set in place core infrastructure and foundations for sustainable healthcare solutions. Reforming health and social care to personalize the home care setting can for example assist in avoiding treatment in a crowed acute hospital setting and improve the experience and impact on both health care professionals and service users alike. In this information intensive domain addressing the interoperability challenge through standards based roadmaps is the lynchpin to enable healthand social care services to connect effectively. Thus facilitating safe and trustworthy data workflow from one healthcare systems provider to another. In this paper we showcase a methodology on how we can extract, transform and load data in a semi-automated process using a Common Semantic Standardized Data Model (CSSDM)to generate personalized healthcare knowledge graph (KG). CSSDM is based on formal ontology of ISO 13940:2015 ContSys for conceptual grounding and FHIR based specification to accommodate structural attributes to generate KG. CSSDM we suggest enables data harmonization and data linking. The goal of CSSDM is tooffer an alternative pathway to speak about interoperability by supporting a different kind of collaboration between a company creating a health information systemand a cloud enabled health service. This pathway of communication provides access to multiple stakeholders for sharing high quality data and information.

Keywords. EHR, FHIR, Ontology, Interoperability, Healthcare System

Introduction

The global crisis caused by the ongoing pandemic, has largely altered the functionality of various service based industries. High on this agenda has been the health and social care industry. The impact on which has been unprecedented. As a consequence, national health and social care programs are progressing action plans to integrate digital as a foundation in future planning of health and social care systems by 2025 *National Health Service (NHS), 2022.* As digital platforms mature in society, people are increasingly cognizant of the potential that technology driven home based solutions can offer. Demand for digital in health and social care is therefore on the increase, both at the servicelevel and service user level. Some examples include convergence of lifestyle products through smart technology, scheduled interactions online, remote monitoring of health conditions and sharing information with health and social care professionals to address unmet needs. For implementing an efficient care plan management system, sole

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analysisof acute hospital summary and clinical care's Electronic Health Records (EHRs) is no longer sufficient. Other core components like individual user needs and social settings should adequately be considered for inclusion. For example the individual living conditions and biography, as well as healthcare information flow, from one healthcare setting(primary care) to another healthcare setting (home care). From a technology perspectiveevidence of urgent requirements include a patient-centric approach, defined access and control, healthcare data models, and integrated reference architecture models and frame-works. All of the above are reported in the evidence as essential in order to progress ac-tion plans for scalable digital solutions to support health and social care. This has been emphasized for example at the proposed *21st Century Cures Act: Interoperability, Information Blocking, and the ONC Health IT* by the US government, Office of the NationalCoordinator (ONC).

From a standards perspective in Europe the, *'Rolling plan for ICT standardization' (2020)* by the European Commission prioritizes on healthcare interoperability, cross-border treatment, and involvement of societal stakeholders in the developmentof EHR systems. Standards such as ISO 23903-*Health informatics — Interoperability and integration reference architecture — Model and framework* focus on ecosystems which offer a harmonized representation to realize interoperability, and advance systemsthat are flexible, scalable, and which can follow a systems-oriented, architecture-centric, ontology-based and policy-driven approach [4].

At the global level the International Organization for Standardization (ISO) 13940:2015–*System of concepts to support continuity of care* provides a conceptual framework to connect patient needs in their complete spectrum of the care journey. Whereas Health Level 7 (HL7) Fast Healthcare Interoperability Resources *FHIR* provides a detailed specification of the various types of resources that can be used to store data in order to address queries on a wide range of healthcare related problems. Less evident in these resources is a semantic data model which can be used for integrated data from across different care settings. Recent studies have shown various advantages of knowledge graphs for the utilization of EHR data and the provision of explicit explainable results to address healthcare queries over time. Knowledge graphs represent the knowledge, relationship and data entities in a formal ontological structure so that the healthcare concepts in the knowledge graph are explicit [10]. In this paper we are providing a fusion model and subsequent steps to demonstrate how OWL 2 Web Ontology Language *OWL2* ontology model can enable data integration from different existing legacy systems using a semi-automated mapping. Our proposed Common Semantic Standardized Data model (CSSDM) aligns with ISO 23903:2021 Health informatics — Interoperability and integration reference architecture — Model and framework [4].

The CSSDM can align with the reference model scenarios such as: An organization working with healthcare and workflow related data, a public healthcare data controller (e.g., Health Service Executive (HSE)/National Services Scotland (NSS)/electronic Data Research and Innovation Service (eDRIS)), or a service which needs to optimize their data preparation pipelines for more efficient use when preparing data for research experiments. A core related issue across these various examples is the need to address data heterogeneity and the tedium processes associated with tackling data heterogeneity in the daily work of the data analysts (e.g., repeated solving of similar heterogeneity issuesin order to maintain an acceptable quality of service to clients). Wider related issues include tackling the interoperability challenge with data from external sources and inter- facing with clients not familiar with local conventions and practices. The remainder of this paper sets in place research conducted on addressing heterogeneity by describing the related work and current challenges in healthcare data modelling, in Section 2. In Section 3 we present our overall methodology and implementation approach, and conclude in Section 4 with a discussion on future work plans and an example of a generatedknowledge graph from our initial development work.

1. Related Works

As part of the development of a standards-based roadmap to enlighten our research, a number of standards were critiqued to inform our decision making and development plan. For example *ISO/AWI TR 24305* Health informatics - Guidelines for implementation of HL7/FHIR based on ISO 13940 and ISO 13606 was reviewed. However it was noted that neither of these resources have to date modified the existing ISO 13940 model, nor included any semantic formalism in their initial work [7]. Earlier work completed by us offered a formal ontology for continuity of care *ContSOnto*[3] using a top-level ontology DOLCE as an upper-level ontology [2] and using OWL as a formal language is cited for background reading.

Key challenges of subsequent work also highlight limited involvement of healthcare professionals in designing and implementing the healthcare information model. For the most part, the health care models are designed by the ICT professionals with very minimalist's involvement of healthcare professional thus such models are ICT-driven ratherthan domain driven for the context of use [5]. Non-standardized and self-defined data models can therefore more often face adoption problems for scaling diverse EHR datasets [11]. FHIR as a resource does not also provide any specific implementation guidelines for context of use or functionality. Examples from different countries such as the USA, which have their own FHIR profile published contrary to a FHIR profile in use by an Indian hospital, indicate that the two FHIR profiles are not interoperable. This supports our review of the evidence that there is no published native FHIR OWL specification which can be used as part of a semantic model. Just a small number of ongoing projects exist that attempt to develop a transformation schema in order to transform FHIR JSON to JSON-LD and then convert it into a Terse RDF TripleLanguage (Turtle) format. In our view, they are however not fit for data integration as they neither followed any ontological principle as suggested by the OntoClean methodology[6], nor clearly make any distinction between the structured attributes and classes. In this paper, we therefore mainly focused on the adoption of a collaborative approach to address these aforementioned gaps. Working with the ISO Health-informatics Technical Committee (ISO/TC 215) and based on experience gained from EU Horizon 2020 *interopEHRate* project, we provide in the following section a summary of the results of our selected methodology.

2. Methodology

We instigate our proposed methodology with two key assumption. The first assumption is not to create another new ontology or create a New Working Item Proposal for another draft standard, but rather use the existing standards and emerging road map to provide solutions to the existing healthcare system issues raised in the introduction section.

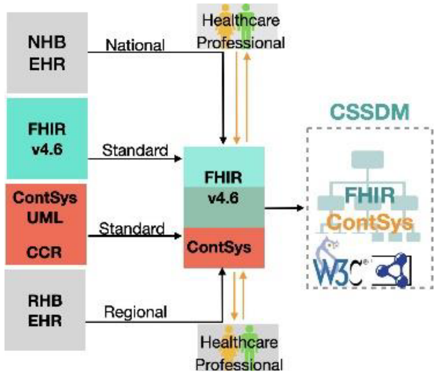

Figure 1. CSSDM Process

The second assumption is re-usability. Our rationale to choose *RDF/XML* is based on the following rationale: The syntax of RDF/XML was the first RDF format created by W3C and it is therefore consideredin the evidence as the standard format. This means that most RDF libraries and triplestore DBs deliver RDF in this format by default. If you therefore want to work with legacy RDF systems or would want to use XML libraries to manipulate your data (as RDF/XML is valid XML), then RDF/XML is the most practical format to use.

ContSys Concept	FHIR Resources
SubjectOfCare:healthcare actor with a person role, who seeks to receive, is receiving, or has received healthcare	FHIR:Patient: Demographics and other administrative information about an individual or animal receiving care or other health-related services.
ObservedCondition: health condition observed by a healthcare actor	FHIR:Observation: Measurements and simple assertions made about a patient, device or other subject.
Request: demand for care where a healthcare professionalasks a healthcare provider to perform one or more healthcare provider activities	No one to one Mapping available
MedicationRequest (New Subclass)	FHIR: MedicationRequest:An order or request for both supply of themedication and the instructions for administration of the medication to a patient.

Table 1. ContSys FHIR mapping

We have analyzed and accommodated view point of ISO 23903:2021—Interoperability and integration reference architecture [4], Care Coordination Measures Atlas [8], and Inference model for future [9] for modelling patient centric view and put foundation to reach the ISO/TS 22272:2021 target state. Overall process of CSSDM shown in Figure1. In Step 1, we have created a Formal Ontology for Continuity of Care details of whichare available in our previous work [3]. In this step we considered and consulted existing available resources relating to information models which we identified as relevant in the context of continuity of care. These included national EHRs, regional EHR models, FHIR resources and Continuity of Care Record (CCR) models, which were then mapped with each other and translated into a formal OWL model. In Step 2, we have presented, discussed and disseminated information about our formal OWL model with the national and international technical committees, which we are engaged with in order to agree and to map concepts based on their meaning. This included exploring concepts such as subject of care and its equivalent to *FHIR:Patient,* and observed condition, which was subsequently mapped with *FHIR:Observation*. In case of *FHIR:Medication Request*, we couldn't find exact mapping in the ContSys resource. We therefore opted to create a subclass of request. The mapping table is presented in Table 1.

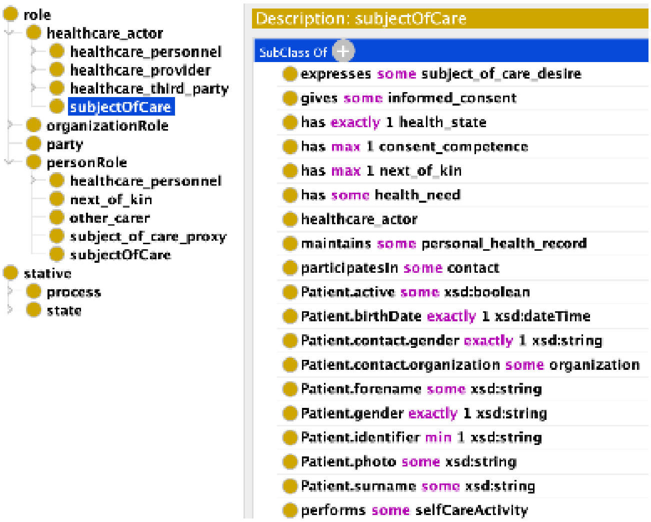

Figure 2. FHIR:Patient attributesinclusion in *Subject of Care*

In Step 3, we have provided a summary of the enriched formal OWL model with the attributes specified in the FHIR resources. Figure 2 shows a snapshot from the editor. On the right, it provides the location of the particular concept in the class hierarchy, i.e., subject of care is a subclass of role. And on the right side, it reflects *all attributes* which are borrowed from FHIR resources.

3. Results and Discussion

We defined Healthcare data interoperability as not a one-time task to solve, but rather a continuous process to deal with in this rapidly changing ICT environment. In this paper, we have provided how to achieve a step in addressing the interoperability challenge by adapting existing model and techniques rather than creatinga new model the way it fits the requirement of the Linked Data approach in or-der to generate an interconnected knowledge graph. In approaching the development using GraphDB, pattern matching can be used to develop a graph as demonstrated in the following Figure 3. Knowledge graphs help in performing complex queries, which are more efficient than join operation in typical relational database.

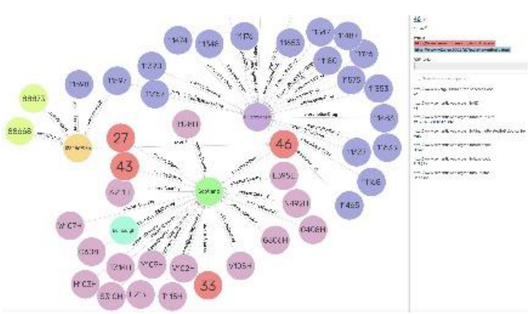

Figure 3. FHIR: Medication Request attributes inclusion

In a number of instances, it is obvious that different organizations when mapping their data to optimize interoperability and address the heterogeneity challenge do not distinguish between the various attributes at the schema level. There are three distinctions to be considered at the schema level 1.

The Common Schema 2. The Core Schema 3. The Context Schema [1]. Lack of a distinction between the different schemas as listed above creates challenges as the core and common attributes more often are the same, however the context of use is not.

Therefore when designing information models it is important to map the ontology based schema for Core and Common only. It is very important to omit the con-text specific attributes, which therefore do not apply to the wider context of use outside ofthe system under development. The example listed above demonstrates this scenario in the case where both the Indian and USA FHIR profiles which are designed for specific use in the context of the organization. They cannot be applied for reuse in other organizations as their profile has implicit meaning which is not interpretable by the machine. As a rule of thumb, we suggest future semantic schema development should only include what is common and core, thus leaving the context-specific attributes to be locally modified based on local needs. In this way advancing interoperability on approx. 80% of the data fields developed using a FHIR based *ContSys* semantic schema available at Github ConstsysFHIR2022.owl.

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References

[1] Bella G, Elliot L, Das S, Pavis S, Turra E, Robertson D, and Giunchiglia F. Cross-border medical research using multi-layered and distributed knowledge. In ECAI 2020, pages 2956–2963. IOS Press, 2020.
[2] Borgo S, Ferrario R, Gangemi A, Guarino N, Masolo C, Porello D, Sanfilippo EM, and Vieu L. Dolce: A descriptive ontology for linguistic and cognitive engineering. Applied Ontology, 3:1–3, 2006.
[3] Das S and Hussey P. ContSOnto: A formal ontology for continuity of care. Stud. Health Technol. Inform. 2021; 285: 82–87.
[4] International Organnization for Standardization (ISO). ISO 23903:2021 Interoperability and integration reference architecture. Geneva: ISO (2021).
[5] International Organization for Standardization (ISO). ISO/TS 22272:2021 Methodology for analysis of business and information needs of health enterprises to support standards based architectures. Geneva: ISO (2021).
[6] Guarino N and Welty CA. An overview of ontoclean. Handbook on ontologies, pages 151–171, 2004.
[7] Kankainen K. Usages of the ContSys standard: A position paper. In ICMDE, pages 314–324. Springer, 2021.
[8] McDonald K, Schultz, E, Albin L, Pineda N, Lonhart J, Sundaram V, Smith-Spangler C, Brustrom J, Malcolm E, Rohn L, and Davies S. Care coordination measures atlas. Agency for Healthcare Research and Quality, Rockville, USA, 2014.
[9] Rector AL, Johnson PD, Tu S, Wroe C, and Rogers J. Interface of inference models with concept and medical record models. In Conference on Artificial Intelligence in Medicine in Europe, pages 314–323. Springer, 2001.
[10] Shang Y, Tian Y, Zhou M, Zhou T, Lyu K, Wang Z, Xin R, Liang T, Zhu S, and Li J. EHR-oriented knowledge graph system. IEEE Journal of Biomedical and Health Informatics 2021; 25(7): 2463–247,.
[11] Tao C, Jiang G, Oniki TA, Freimuth RR, Zhu Q, Sharma D, Pathak J, Huff SM, and Chute CG. A semantic-web oriented representation of the clinical element model for secondary use of EHR data. Journal of the American Medical Informatics Association 2013; 20(3): 554–562.