

Interoperable E-Health System Using Structural and Semantic Interoperability Approaches in CAREPATH

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Abstract. Technical and semantic interoperability are broadly used components of interoperability technology in healthcare. Technical Interoperability provides interoperability interfaces to enable data exchange within different healthcare systems, despite any underlying heterogeneity. Semantic interoperability make different healthcare systems understand and interpret the meaning of the data that is exchanged, by using and mapping standardized terminologies, coding systems, and data models to describe the concept and structure of data. We propose a solution using Semantic and Structural Mapping techniques within CAREPATH; a research project designed to develop ICT solutions for the care management of elderly multimorbid patients with mild cognitive impairment or mild dementia. Our technical interoperability solution supplies a standard-based data exchange protocol to enable information exchange between local care systems and CAREPATH components. Our semantic interoperability solution supplies programmable interfaces, in order to semantically mediate different clinical data representation formats and incorporating data format and terminology mapping features. The solution offers a more reliable, flexible and resource efficient method across EHRs.

Keywords. Technical interoperability, Semantic interoperability, HL7 FHIR

1. Introduction

Parallel to the rapidly growing technologies in healthcare, interoperability has become a critical step for the successful integration of technologies and systems. Interoperability

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enables different health systems, applications and devices communicate, exchange data and work together effectively to improve patient experiences, care and outcomes and reduce costs and errors [1]. Interoperability is a prerequisite of data sharing between the multidimensional stakeholders in healthcare [2]. Otherwise, the communication between heterogeneous players could be hindered by several aspects of health systems, including contradicting rules and variable ontologies [3]. It requires two distinct aspects of compatibility: a structural aspect that refers to data schema and mapping protocols and a semantic aspect that targets the common concepts understood and utilized both by humans and machines [4]. Several standards have been proposed including the Fast Healthcare Interoperability Resource (FHIR) Health Level Seven International (HL7) standard that has become increasingly popular in digital health [5].

CAREPATH is a research project designed to develop ICT solutions, through an integrated approach for the care management of elderly multimorbid patients with mild cognitive impairment or mild dementia. This holistic patient-centred approach requires robust interoperability measures [6]. In this paper, we will discuss the concept and applicability of the interoperability approaches in healthcare and introduce an implemented model used in the CAREPATH project.

2. Interoperability Architectural Concept for Connected-Health Technology

Technical and semantic interoperability are broadly used components of interoperability technology in healthcare. Within the CAREPATH project, the Technical Interoperability Suite (TIS) provides interoperability interfaces to enable seamless data exchange with the local care systems although the data exchange protocols and clinical data representation formats may be heterogeneous across various communicating components, and IT systems used in collaborating connected-health sites.

The Semantic Interoperability Suite (SIS) makes different healthcare systems understand and interpret the meaning of the exchanged data by using and mapping standardized terminologies, coding systems and data models to ensure the data keep the concept, structure, and actual meaning. In high-level general interoperability architecture TIS receives a request for data from the calling-service-provider and queries the called-service-provider. Then it uses the structural and terminology mapping services provided by the SIS. SIS maps differing format data into the appropriate structure via its Structural Mapper and passes codable concepts to the Semantic Mapper portion of SIS and maps concepts between different standards. Finally, SIS Structural Mapper portion reconstructs the message with the translated codes and concepts and then TIS pushes data into the repository to be used by other services.

3. CAREPATH Component Integration

In the CAREPATH project, all components are integrated based on the above-mentioned high-level general interoperability architecture. All modules are integrated with the central HL7 FHIR-based patient data repository, named onFHIR.io, to share or receive medical data of the patients and care plan-related data. onFHIR repository is secured with the Security and Privacy Suite (SPS) to authenticate and authorize users via role-based rules. All clients access the FHIR repository with REST APIs and can also subscribe to the data changes to receive instant notifications with the subscription engine

provided by onFHIR. The FHIR repository is integrated with the local EHR systems via the TIS to make the local patient data available in the AICP and PEP. TIS converts the patient data in local systems to HL7 FHIR format and sends them to the onFHIR repository.

4. Interoperability Suites in the CAREPATH Architecture

In CAREPATH, TIS mainly aims to supply patient site data from local care systems to the FHIR repository via a querying mechanism. It uses SIS to transform the data from heterogeneous sources into a standardized format before saving it in the central data repository. Using the SIS to address content-level interoperability challenges, TIS supplies a standard-based data exchange protocol to enable information exchange between local systems and CAREPATH components. SIS supplies interfaces to semantically mediate different clinical data representation formats of CAREPATH components and local sites, incorporating data format and terminology mapping features.

5. Overview and Internal Architecture of TIS

The CAREPATH TIS handles two kinds of queries. The first type of query is for retrieving/updating patient data from local EHRs, while the latter is for the scheduling of automated data imports. The TIS application handles the connection to local care-provider EHR systems for the retrieval of patient data from individual care sites and individual bespoke data services are defined within the application for the partner's site for this purpose. The SIS Client component of the TIS application defines the methods necessary for handling the connection with SIS and the retrieval of the transformed data.

The importing sequence is articulated by the Import Processor component which interacts with the central FHIR repository via the FHIR Client component. It defines the necessary methods for the connection, retrieval and saving patient data. Imports can be initiated from the clinician portal while the definition and running of imports following pre-defined fixed schedules are handled by the Import Scheduler component.

6. Overview and Architecture of SIS

CAREPATH SIS is a RESTful API that manages the mapping of message formats into FHIR or other defined format between different systems. Structural Interoperability presents structural data using FHIR international standards. This data is presented using predefined standards in XML (extensible markup language). The data that is sent from one API is intercepted using structural interoperability and is transformed into another structure as required by another receiving API meeting the required data formatting standards. Semantic Interoperability refers to the change of data from one predefined format to another expected one without any change in concept and meaning. SIS uses a bespoke Transform Template format to transform message bodies between systems. SIS stores Transform templates in an external repository. SIS can also use transform templates for the transformation of route parameters on bodyless send messages. TIS will send non-FHIR format data to be transformed to FHIR via SIS. Finally, SIS will

send a message containing the transformed data suitable to be stored in the FHIR repository back to TIS.

7. TIS and SIS Development and Implementation Model

TIS uses SIS to address content-level interoperability challenges. SIS supplies interfaces to semantically mediate different clinical data representation formats used by CAREPATH components and local care sites, incorporating data format and terminology mapping features [7]. They are built on the Structural and Semantic Mapping API Proxy that can receive GET, PUT, POST or DELETE messages from a Sending API. When a POST or PUT message is received from Sending API to Proxy API, it uses a call-back method to carry out the mapping from a Source Schema to Target Schema. Then Proxy API uses call back message to call back Receiving API route as listed in Open API schema. The designed and developed interoperability suits handles fetch/pull and push mechanism through API connectivity service.

8. Conclusion

We propose a solution for an integrated E-Healthcare System using Semantic and Structural Mapping. This domain has potential future applications in research and industry as interoperability tools can be embedded and used in the daily operation of EHR systems.

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References

- [1] de Mello BH, Rigo SJ, da Costa CA, da Rosa Righi R, Donida B, Bez MR, et al. Semantic interoperability in health records standards: a systematic literature review. *Health and Technology*. 2022;12(2):255-72.
- [2] Saripalle R, Runyan C, Russell M. Using HL7 FHIR to achieve interoperability in patient health record. *Journal of Biomedical Informatics*. 2019;94:103188.
- [3] Kiourtis A, et al. Aggregating the syntactic and semantic similarity of healthcare data towards their transformation to HL7 FHIR through ontology matching. *International Journal of Medical Informatics*. 2019;132:104002.
- [4] Arvanitis TN. Semantic interoperability in healthcare. *Studies in Health Technology and Informatics* 2014;202:5-8.
- [5] Ayaz M, Pasha MF, Alzahrani MY, Budiarto R, Stiawan D. The Fast Health Interoperability Resources (FHIR) standard: systematic literature review of implementations, applications, challenges and opportunities. *JMIR Medical Informatics*. 2021;9(7):e21929.
- [6] Pournik O, et al. CAREPATH: Developing Digital Integrated Care Solutions for Multimorbid Patients with Dementia. *Studies in Health Technology and Informatics*. 2022;295:487-90.
- [7] Peake AR, et al. Structural and Semantic Mapping of Application Programming Interfaces. *Studies in Health Technology and Informatics*. 2022;295:478-82.