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ELGA Terminology Server for Clinical Decision Support: A Case-Study Using an Existing Knowledge Base, CDS Hooks and FHIR

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Abstract. Background: There are many medical knowledge bases with potential for supporting medical professionals in their decision-making during routine care, yet usage of these sources remains low. Standardized linking of Clinical Decision Support (CDS) applications and existing medical knowledge bases is not a common practice. Objectives: Using existing eHealth standards to increase the utilization of knowledge bases and implement a prototype. Methods: Linking an existing online knowledge base via a FHIR *CodeSystem supplement* to the Austrian national EHR (ELGA) terminology server and accessing these data using CDS Hooks and FHIR. Results: We tested the approach by incorporating photosensitivity data of medications into a local copy of the Austrian terminology server. These data are directly used by a CDS Hooks compliant CDS service. Conclusion: The Austrian Terminology Server could be an important interface to access existing knowledge bases from within EHR systems. FHIR and CDS Hooks could lead the way for a simple and open integration of CDS services into EHR systems.

Keywords. Decision Support Systems, Health Information Interoperability, Systems Integration, Health Information Exchange, Decision-Making, Health Information Systems, Medical Records Systems, Knowledge Bases

1. Introduction

Clinical decision support (CDS) systems support clinical decision-making of medical professionals by using algorithms to generate recommendations based on provided input data. CDS systems can be directly implemented into electronic health record (EHR) systems or as standalone software systems. Previous studies identified problems which invalidate and restrict their usefulness and could be a reason for the low adoption rate of CDS systems. CDS systems may slow down the workflow of a medical professional, and navigating to another system may be burdensome to them [1, 2]. Another common shortcoming of CDS systems is the so-called "alert fatigue" due to excessive display of notifications, leading professionals to stop reading these notifications altogether [1, 3–

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5]. Additionally, medical professionals want to keep their autonomy when making decisions and not blindly rely on what a system tells them [1].
Development of CDS systems is subject to medical device regulations, which may raise questions and be seen as obstacles to innovation by software producers [6]. Yet, to enable evidence based medicine, medical professionals need to rely even more on external knowledge sources to ensure proper medical treatment. Medical societies provide online curated information based on current literature, examples are embryotox.de to offer information on tolerance of drugs in pregnancy, kindermedika.at with information on off-label applications of medication for children or phototox.org which offers information on previously reported drug-induced photosensitizing side effects in literature.

As part of the Austrian national EHR system (ELGA), a new terminology server[2] providing all necessary terminologies for the Austrian healthcare system was launched. It is based on the distributed version control system GIT to facilitate a transparent approval and change process of medical terminologies. This also allows an easy deployment on-premise by cloning of the terminology server. The terminologies are internally persisted based on the HL7® fast healthcare interoperability resources (FHIR®) format and legacy export formats of the terminologies are generated automatically.

CDS Hooks[3] were developed as an extension to the SMART on FHIR[4] standard. Watkins, et al. [7] developed a prototype that extracts data from PDF lab reports that could be relevant for future doctor visits into machine-readable lab reports, using CDS Hooks, that automatically display extracted information in the form of CDS Hooks *cards* when a patient record gets opened. CDS Hooks by SMART® are gaining more and more popularity [8] and are a promising approach to integrate CDS into EHR systems [9, 10].

The goal of this work was to develop a concept to easily access existing medical knowledge sources from within EHR systems. Using the ELGA terminology server as a standardized knowledge base and the emerging CDS standards CDS Hooks and FHIR we implemented a prototype to evaluate this approach. We focused on the technical feasibility and the interaction of the different components involved, and not on the requirements needed for the approval as a medical device.

2. Methods

To enable standardized access to existing knowledge bases, we propose to use the FHIR *CodeSystem supplements* to link knowledge to existing terminologies in the ELGA terminology server. In combination with CDS Hooks, the linked knowledge can be made available directly inside the EHR systems and support clinicians in their decision processes. To evaluate the proposed approach, an existing open knowledge base with additional information to medications was prepared and added to a local copy of the ELGA terminology server via *CodeSystem supplements*. For the implementation, we chose the Python programming language and the Flask framework inside of Docker containers to easily test and deploy the system locally.

Our prototype is used to evaluate CDS Hooks as an interface between EHR systems and CDS services. To test the communication and conformation to the CDS Hooks

[2] https://termgit.elga.gv.at/

[3] https://cds-hooks.org/

[4] https://smarthealthit.org/smart-on-fhir-api/

specification, we used a self-developed mock EHR system and the SMART Dev Sandbox[5].

3. Results

We implemented a CDS Hooks compliant CDS system that loads the needed data from the ELGA terminology server, caches it in a local FHIR Server and is triggered by actions in a mock EHR system via a CDS hook from the CDS Hooks specification. Figure 1 shows an overview of the implemented prototype and how the components of the prototype interact with each other.

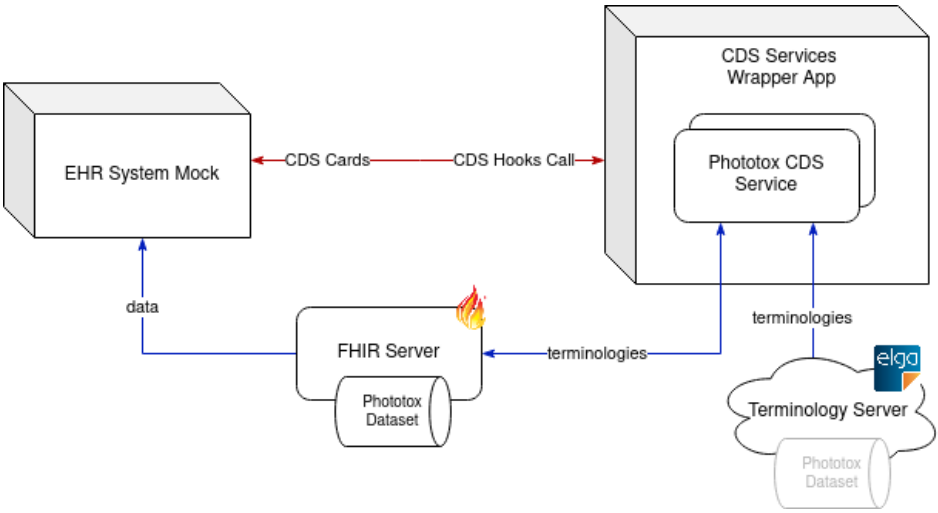

Figure 1: Overview of the developed prototype. The EHR system mock triggers the CDS service and displays the CDS Hooks *cards*. The FHIR server is used to persist the data. The CDS services wrapper app with the Phototox CDS service loads the needed data from the ELGA terminology server.

The CDS services wrapper app is the main component of our prototype. It implements the required services endpoints from the CDS Hooks specification and executes the logic of the CDS service. The two hooks *patient-view* and *order-select* can be triggered based on the use case in the EHR system.

We chose the Phototox.org knowledge base as a sample data for our CDS service and called it the Phototox CDS service. The CDS services hosted by the application are two explorations of clinical decision support that can be provided with the Phototox.org dataset. Phototox.org is a web portal aimed to aid dermatologists in identifying photosensitizing agents in medication. The web page displays summaries of information gathered from publications which mentioned their photoallergic and phototoxic potential. A study showed the potential of this dataset to significantly increase the accuracy and speed of identifying photosensitizers [11].

When performing checks on potentially photosensitizing medication, for example before sending a patient to phototherapy, dermatologists should be able to open the

[5] https://github.com/smart-on-fhir/smart-dev-sandbox

patient record in the EHR system whilst this action internally activates the *patient-view* CDS hook of the Phototox CDS service. The EHR system calls the CDS service and includes prefetched medication data of a patient. The medication data have to include the ingredient using the World Health Organizations's Anatomical Therapeutical Chemical (ATC) classification code. The Phototox CDS service receives and determines if any medication that is prescribed to the patient is part of the dataset, which in turn triggers the generation of the CDS Hooks *cards* that get displayed by the EHR system. Another action, which activates the generation of CDS Hooks *cards*, is choosing a medication to prescribe in the EHR system's graphical interface. Following this action, the second Phototox CDS service is activated by the *order-select* CDS hook and a similar procedure with a selected medication's ATC code is started.

In order to perform checks on the medication data, the Phototox CDS service is making sure to have a current version of the ATC code system in a local FHIR server by fetching the current version from the Austrian terminology server's repository via the Gitlab API. The Phototox CDS service generates a *CodeSystem supplement* which lists all concepts from the Phototox.org dataset and assigns attributes containing further information to them, which can be used to generate CDS Hooks *cards*. A proposed *CodeSystem supplement* is shown in figure 2.


```
{ "resourceType": "CodeSystem",
  "id": "phototox-supplementt",
  "name": "phototox-supplement",
  "status": "draft",
  "experimental": true,
  "content": "supplement",
  "supplements": "https://termgit.elga.gv.at/CodeSystem-atc-deutsch-wido",
  "property": [
      {"code": "phototox_id",
      "description": "Identifier in the Phototox database",
      "type": "string"},
      {"code": "publication_count",
      "description": "Count of publications that report photosensitizing
effects caused by this drug",
      "type": "integer"}],
  "concept": [{
      "code": "C03AA03",
      "display": "Hydrochlorothiazid",
      "property": [
          {"code": "phototox_id",
          "valueString": "0"},
          {"code": "publication_count",
          "valueInteger": 41}]}]}
```


Figure 2. A JSON excerpt of the *Phototox CodeSystem* supplement with an example concept.

The *Phototox CodeSystem supplement* is intended to supplement the ATC code system provided by the ELGA terminology server. We integrated this new terminology into a clone of the ELGA terminology server. The Phototox CDS service caches the *CodeSystem supplement* fetched from our terminology server in the local FHIR server and accesses it on demand.

The developed EHR system mock was good for evaluating dynamically produced calls and testing for the desired output. Part of the evaluation was checking if the data is in a correct format, specifying the exact type of information and data EHR systems as well as CDS services need, and which parts of the data remain optional. To test the generalization of our approach, we connected the SMART Dev Sandbox to our CDS service and tested the *patient-view* CDS hook. These tests showed that our CDS service conforms to the specification and can be triggered from other CDS Hooks in other EHR systems as well.

4. Discussion

Since the medical field is a high risk environment, clinical software needs to be thoroughly tested in order to be allowed onto the market [6, 12]. Our prototype is a simple study of new technologies and components, but to release CDS software, software manufacturers who seek to certify their software as medical device have to analyze which risk class applies to their CDS service. A categorization is not simple, it depends on the intended market (e.g. USA or EU) and may be different depending on the used algorithms like more explainable knowledge-based rules or complex statistical models [6].

The testing of the *order-select* CDS hook was limited by SMART Dev Sandbox's focus on the American market with their FHIR profiles, which for example use RxNorm encoded medications instead of the ATC codes used in Austria. However, all parts of this sandbox environment are open source and could be modified for the developer's need by building an own customized test environment.

For a CDS service, one has to consider which patient data it needs to perform its logic and how this data is formatted. Since FHIR is still an emerging standard, sometimes there are not many base profiles and specifications for a certain country or system available. Ideally, a CDS service should be developed separately from an EHR system to be usable by any EHR system. Especially if the developer wants to be able to integrate it into many systems worldwide. Differences in coding of certain fields in the data may render this task difficult if a CDS service expects a specific code system not used in another country or region. A possible solution could be looking into mappings of different code systems and applying these as part of the CDS service.

To upload a new terminology to the terminology server, it should go through several approval processes and should be backed by a medical society. Phototox.org is a relatively new knowledge base, it is not yet officially managed by a medical society and a quality assurance with a scientific advisory board still has to be established. It should be decided which data should be displayed in a CDS Hooks *card* and which data will be linked externally via the web portal and then allowed by ELGA to be added to the terminology server.

In summary, CDS Hooks as well as the use of FHIR are great additions to the digital medical environment. CDS Hooks are simple to implement and are already supported by the SMART standard to easily integrate them in EHR systems. Current eHealth standards may ease the development of many new CDS services to support medical professionals in their day-to-day work.

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