Clinical Predictive Modeling Development and Deployment with OMOP CDM and FHIR

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Abstract
Clinical predictive modeling involves two challenging tasks: model development and model deployment. In this work, we demonstrate a software architecture for developing and deploying clinical predictive models using web services via the Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR) standard. The services enable model development using electronic health records (EHRs) stored in OMOP CDM databases and model deployment for scoring individual patients through FHIR resources. The EHR data are transformed into OMOP CDM databases for predictive model development. The resulting predictive models are deployed as FHIR resources, which receive requests of patient information, perform prediction against the deployed predictive model and respond with prediction scores. To assess the practicality of this approach we evaluated the response and prediction time of the FHIR modeling web services. We found the system to be reasonably fast with one second total response time per patient prediction.

Introduction
Clinical predictive modeling research has increased because of the increasing adoption of electronic health records. However, the dissemination and translation of predictive modeling research findings into healthcare delivery is often challenging. Most predictive modeling research ended with just publications without actually deployment of model into operational settings. Significant gap around health data and process standardization prohibits predictive modeling deployment. We propose an open architecture for predictive modeling development and deployment using two important health interoperability standards (OMOP CDM and FHIR resources). In particular, OMOP CDM is used as the data store for supporting predictive model building, while extended FHIR resources are used to deploy a predictive model for scoring future patient encounters. Thanks for the growing acceptance of both standards, we believe the proposed predictive modeling frame can enable broader adoption and easy integration to the underlying electronic health records (EHR) systems. In this work, we describe an overall architecture using OMOP CDM for predictive model development and extending FHIR for model deployment.

Methods
In this section, we first describe the overall architecture then we describe predictive model development and deployment process in details.
System Overview
Figure 1 depicts the overall architecture of the system. We logically divide it into three components: model development and model deployment. The model development component processes input data in the OMOP CDM format and generates multiple predictive models that clinical researchers can then select to export for deployment. Then the FHIR server will use the exported model via a model adapter for predict certain target such as drug effectiveness or readmission risk. Finally, the FHIR client, which can be a mobile App or decision support application inside the EHR system, will take patient data to RESTful API provided by FHIR server to make predictions.

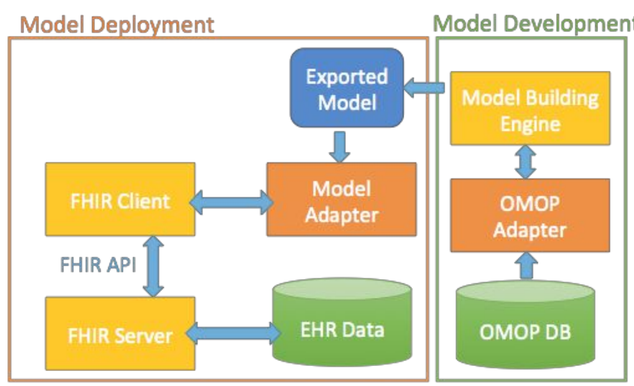

Figure 1. Predictive modeling architecture

Model development with OMOP

The model development is mainly conducted on our parallel predictive modeling platform [1]. Initially, the input data are converted into OMOP CDM format. Such Extract, Transform and Load (ETL) processes are usually outside of our core system and customized input data adaptor needs to be developed for a given data source. Next, the OMOP Adapter we developed will convert the OMOP data into our internal JSON format. Reason why we need another conversion rather than directly use the OMOP CDM is that the CDM is defined as relational data schema, which is ideal for large scale parallel computation. In this step, not all patient data need to be converted, user can specify relevant tables and data fields to be converted, e.g., only condition occurrence and drug exposure table. Finally, multiple predictive models will be built in parallel (see [1] for details). User can select the best suitable model for export.

Model deployment with FHIR

FHIR provides RESTful API URL patterns for create, read, update, and delete (CRUD) operations which allows us to have an API-based predictive modeling service. Resources in FHIR are represented as JSON or XML objects and can contain health concepts along with reference and searchable parameters. We use the *RiskAssessment* resource defined in the FHIR Draft Standard for Trial Use 2 (DSTU2) for our predictive analysis.

In order to request scoring for specific patients, a CREATE operation must be sent to the FHIR server. The clients must provide the appropriate elements in the *RiskAssessment* resource when sending the CREATE request. For our predictive model, the *RiskAssessment* resource is constructed using the *subject*, *basis*, and *method* elements. *Subject* is used to define a Patient reference or a Group identifier containing multiple patients to which the risk assessment applies. *Basis* can contain information used in assessment, such as the prediction index date and time window. *Method* is optional, and if provided, it specifies which predictive model to use as there can be multiple models deployed together. Once the request is received, the deployment server uses the FHIR client to retrieve patient data from FHIR enabled EHR using the patient reference specified in the *Subject*. Received patient data will then be mapped to a patient feature profile to be used for scoring by the deployed predictive model. Received patient data includes but is not limited to *Condition*, *Observation*, *Procedure*, and *MedicationAdministration* in FHIR resources. *Basis* in the *RiskAssessment* request is used for the time-window filtering for received patient data. The scoring for the patients occur in real-time. SMART on FHIR is used for authentication and authorization while retrieving data from EHR via FHIR. A *RiskAssessment* resource is created at the server and the client applications receive a status response with the *resource identifier* representing this newly created resource. The server also stores the information associated with the newly created resource in the resource database. Since OMOP does not provide a table for prediction results, a new table is created with the same OMOP concept ids mappings. Client Apps can query the prediction results using the *resource identifier* returned in the CREATE response by using the SEARCH operation. The FHIR server constructs a response FHIR resource for each patient associated with that prediction. Figure 1 depicts how FHIR plays its role in our predictive mode deployment approach.

Conclusion

We introduced a open source clinical predictive model development and deployment platform. Along with OMOP CDM and FHIR for our model deployment and health information exchange, we were able to deploy clinical predictive models for clinical decision support. This architecture can be applied and extended to various health platforms where clinical decision supports are needed. Furthermore, the baseline architecture is closely integrated with FHIR and OMOP CDM. Any FHIR enabled EHR can adopt this open platform without major changes to their internal systems and workflows.

References

[1] Khalilia, Mohammed, Myung Choi, Amelia Henderson, Sneha Iyengar, Mark Braunstein, and Jimeng Sun. "Clinical Predictive Modeling Development and Deployment through FHIR Web Services," AMIA 2015.