Quality of Life through Quality of Information
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Towards Collaborative Chronic Care Using a Clinical Guideline-Based Decision Support System

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Abstract. Few clinical guideline-based decision support systems (DSS) have been successfully applied in chronic disease management. This paper investigates how clinical guideline-based DSS can help to put innovative chronic care models into practice and improve the quality of chronic care. A prototype of a guideline-based collaborative chronic care system called GC3 was developed based on a framework integrating guidelines into care workflow where a business process engine and a GELLO-based decision engine are integrated together to execute guidelines. We deployed the system in one of the largest hospitals in China and its affiliated community centers in order to manage type 2 diabetic patients. Pilot use of GC3 demonstrates its benefits to regional chronic care including evidence-based decision support, shared care content, improved clinician adherence to guidelines and enhanced patient self-management. This study verifies the feasibility and effectiveness in implementing collaborative chronic care across health providers using clinical guideline-based DSS.

Keywords. Decision Support, Chronic Care, Clinical Guidelines

Introduction

During the past decade, there is an increasing effort to develop guideline-based decision support systems where the core task is to implement computer interpretable guidelines (CIG) [1]. However, the work has largely focused on decision support tasks in acute care so that physicians can be provided the right recommendations at individual points of care rather than processes of care. Compared to acute care, besides an evidence-based approach the crucial factors of improving chronic care also include integrating decision support into a complex care workflow, implementing effective patient self-management, and developing an efficient communication mechanism among care providers and patients.

In order to address the above issues, we have developed a guideline-based collaborative chronic care system prototype named GC3. The goal of this paper is thus to describe the system and demonstrate our innovative approach. In specific, our work contributes to (1) developing a collaborative system framework to streamline chronic care processes across multiple health providers by executing clinical guidelines; (2) executing clinical guidelines by integrating a business process management (BPM)

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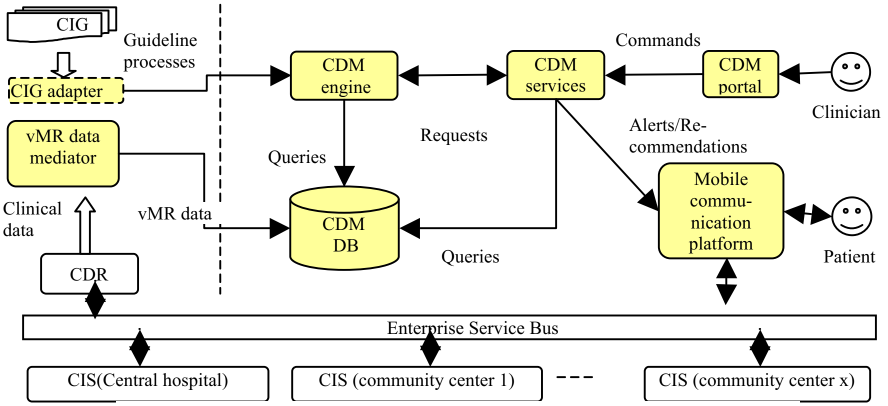

Figure 1. Guideline-based CDM system GC3.

engine and a novel decision engine which evaluates clinical criteria conforming to the HL7 GELLO standard [2]. By embracing the open standards, our computerized guidelines can be reused and executable by other standard-compliant guideline-based decision support systems.

GC3 is designed with a service-oriented architecture and flexible to be deployed in various clinical settings. With the proposed approach, the guideline knowledge could be seamlessly integrated into chronic care workflow and promote the clinicians' compliance with guidelines and patients' adherence to clinical advices in the course of chronic care, so as to effectively improve the CDM quality.

1. Methods

Figure 1 depicts the overall architecture of GC3 which currently provides the following main functionalities: 1) Providing clinical recommendations (lifestyle intervention, and drug therapy and so on) to clinicians according to the underlying guidelines; 2) Supporting patient self-management activities by sending health reminder, alert messages to a mobile communication platform (MCP) which forwards the messages to patients; 3) Sharing key clinical activities and data of managed patients to meet the collaboration needs from different health providers; 4) Identifying clinical activities that are not complied with the underlying clinical guidelines.

We briefly describe the key components of GC3 as follows: an **vMR data mediator** is developed to interact with an external Clinical Data Repository (CDR) from which relevant chronic care data for patients can be retrieved. CDR is a real-time database that consolidates data from a variety of external clinical information systems (CIS) to present a unified view of a single patient, and can be implemented in various forms. The data mediator then transforms the collected data into a standard form – vMR [3] which is an underlying data model for GELLO language, and stores them into **CDM DB**. The mediator is also responsible for updating CDM DB in response to the source changes which are propagated though an Enterprise Server Bus. CDM DB is a hybrid repository of CDM application-specific data and clinical data for guideline execution. The critical clinical data to decision-making are derived from external data sources and stored into the database in the form of vMR (XML fragments), while CDM application-specific data are generated during interactions with **CDM portal** and stored in relational form. CDM portal acts as a unified user interface of GC3 system through

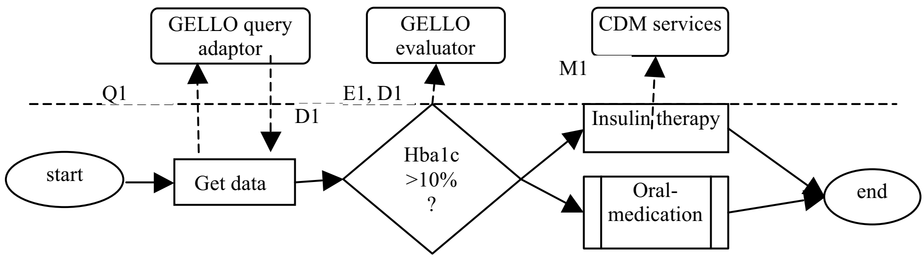

Figure 2. GELLO-based decision support for CDM applications.

which all clinical information pertaining to caring a patient with chronic conditions is shared among the authorized clinicians regardless of their office locations.

CDM engine is the core component of the system and responsible for executing clinical guidelines to provide care recommendations. In order to align the execution of guidelines with a specific chronic care process/plan, the guidelines are first computerized into standard (XPDL)-based business processes. These guideline processes are then deployed in this standard-compliant BPM engine and ready to be executed through **CDM services** which are developed to support external components/systems for CDM functionality, including registering/deregistering patients into CDM programs, executing CDM processes, dispatching health messages (alerts/reminders, recommendations), retrieving/recording incompliance and so on.

MCP takes responsibility of bridging over patients and GC3. Relying on MCP, patient data measured at home is passed to GC3, and physician decisions generated from GC3 are passed back to patients' mobile phones through various communication channels (e.g. short messages, voice, mobile widgets). In addition, we propose to develop a **CIG adapter** that transforms different guideline representation models (GRM) into a XPDL standard-based representation form which is well supported by existing BPM engines. We will not elaborate on MCP and CIG adapter as they are beyond the focus of this paper.

We now elaborate on how guidelines are executed using CDM engine. Figure 2 shows a simple example how the components of CDM engine: BPM engine, GELLO evaluator, GELLO query adaptor and CDM services collaborate together to generate guideline-based therapy recommendations. Whereas existing guideline execution engines are mainly proprietary developments by CIG models' authors, GC3 employs a BPM engine as an interpreter of the guideline process model where logic flow of guidelines can be integrated into the process flow of chronic care. Meanwhile, the BPM engine invokes a GELLO query adaptor to access the necessary clinical data and a GELLO evaluator to evaluate clinical conditions whenever a decision-making is needed during the care process. (As few GELLO implementations are publicly available in use, please refer to [4] for our own implementation of GELLO evaluator so as to provide standard-based decision support for the CDM engine).

The lower part of the figure depicts a guideline process to recommend therapy methods for a patient who is diagnosed diabetes at the first time. The process running on a BPM engine first invokes GELLO query adaptor to send a query Q1 in GELLO language to retrieve the patients' latest HbA1C test result from CDM DB. The result D1 representing an HbA1C observation with value of "11%" is returned as an vMR data and accessible by the process instance. Then the process invokes GELLO evaluator to compute if the patient's HbA1c result is larger than the threshold value

"10%" represented by a GELLO expression E1, and generates the therapy advice M1 of "applying insulin injections" accordingly. The message M1 is sent to the interested collaborators through calling a specific CDM service. Table 1 shows the example data used in this process.

Table 1: Example data used in guideline-based CDM processes.

Data	Data standards
Q1 package VMR context Patient def: HbA1c : CD = factory.CD('LOINC', '4548-4', 'Hemoglobin A1c, B') self.isAssociatedWith -> select(oclIsTypeOf(LaboratoryObservation)).oclAsType(LaboratoryObservation)) -> select(testCode.equal(HbA1c)) -> sorted(effectiveTime) -> first	GELLO
D1 <LaboratoryObservation classCode="OBS" moodCode="EVN"> <testCode code="4548-4" codeSystem="2.16.840.1.113883.6.1"codeSystemName="LOINC" displayName=" Hemoglobin A1c, B"/> <status code="completed"/> <effectiveTime value="20104071530"/> <value xsi:type="PQ" value="11" unit="%"/> </LaboratoryObservation>	vMR
E1 package VMR context Patient def: HbA1c : CD = factory.CD('LOINC', '4548-4', 'Hemoglobin A1c, B') def: HbA1c_threshold : CD = factory.PQ('10', '%') self.isAssociatedWith -> exists(testCode.equal(HbA1c) and value.greaterThan(HbA1c_threshold))	GELLO
M1 <advice><advice_type>therapy</advice_type><content>"Applying insulin injections"</content> </advice>	Service message

2. Results

We have successfully deployed the system prototype in one of the largest health provider, namely Peking University People's Hospital (PKUPH), in China, a tertiary hospital collaborating with over 50 community health centers. As a start, the system has implemented a regional care program for patients with type 2 diabetes where clinicians can enroll selected diabetic patients for management.

The underlying diabetes management guideline is based on a national guideline for diabetes management in China [5]. We have worked closely with the domain experts from PKUPH to computerize the guideline into an executable care process composed of 32 sub-processes where 271 clinical steps and 41 clinical decision points are defined. All these processes are defined based on XPDL standard and deployed in an industry BPM engine FileNet P8 (version 4.5.1). Because the processes are defined based on the standard clinical guideline and independent of particular clinical applications, they are potentially sharable among different health institutions. In response to the change of patient states, the system executes the care process and recommends from the 18 alternate therapy advices. In addition, the system sends 7 kinds of follow-up reminders including HbA1C and blood lipid measurements, eyeground examination, and so on, 5 kinds of health alerts including hyperglycemia, high blood pressure, and so on, and care education messages to MCP which forwards the messages to diabetic patients.

On the other hand, the system provides critique on physicians' past decisions in order to analyze guideline compliance and improve guideline in the future.

Compliance degree for a physician is qualitatively divided into good, fair, and bad levels, and the portal displays the overall distribution of physicians' compliance degrees for a specific institution or all collaborative institutions. Furthermore, GC3 allows physicians to input reasons why they fail to follow the guideline in their therapy, which is useful for adapting the guideline to a local environment.

3. Discussion

Existing work on CIG mostly focuses on guideline representation formalisms and the execution of these CIG is mostly based on ad-hoc engines for particular guideline formalisms [1]. In contrast, we have developed an executable standard-based guideline approach to support CDM workflows and decision-making where multiple health providers including patient himself collaborate together to improve care quality for a long term. The approach computerizes guidelines as executable business processes by standard-based BPM engines, and provides GELLO-based decision support which inherently makes it easy to be adopted by chronic care workflows across different institutions. Recent work [6] also developed similar approach to execute guidelines using a generic BPM engine. However, it does not support vMR-based patient model and GELLO-based decision-making, and is limited to be applied in a specific clinical care setting, and thus does not fit for a generic chronic care environment.

Arguments always exist about how to effectively deliver guideline-based decisions to clinicians' daily practices. Due to the requirement of not to interfere with the current CIS at the current stage, we deployed the GC3 prototype in a passive mode where clinical decisions are derived in response to data captured by vMR data mediator from CIS, and can be viewed through the independent CDM portal. In other words, invocations of decision-making are decided by the update pattern of vMR data mediator. However, by nature of service-oriented architecture of GC3, the system is enabled to work in a proactive mode as well where CIS can directly interact with the CDM services to feed clinical data to the CDM engine and receive system recommendations in real time. This proactive mode is considered to be deployed in the next stage of our project with PKUPH. Another limitation for our work lies in that GC3 currently provides therapy advice only while chronic care needs decision support over the full disease stages including prevention, diagnosis, treatment, and prognosis. We will explore this in the future work.

In summary, we demonstrated an integrated guideline-based CDM engine using BPM and decision support techniques by following open standards, and expect to close the gap between innovative chronic care models and practical CDM systems in use.

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