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A Design Science Approach to Modelling and Facilitating Clinical Workflow and Decision Making

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Abstract

Objectives:

This paper reports on the use of emerging process modelling standards in enhancing the development of guideline-based DSS.

Background:

Benefits from guideline-based DSS are yet to be fully realized largely due to poor integration with clinical workflow, poor integration with EHR and/or other clinical systems and lack of easy transportability and assimilation. Developments in eCommerce associated with automation of the integration of heterogeneous systems and agent choreography can potentially answer some of the challenges in clinical DSS development. In an earlier paper, we developed an approach to clinical DSS based on the Business Process Execution Language (BPEL) and Web Services. This paper further develops the approach and discusses the use of a visual modelling language to transform clinical workflow to executable guidelines by means of an automated mapping.

Methods:

A design science approach is used. Several process modelling languages were reviewed for suitability for guideline automation and integration. The Business Process Modelling Notation (BPMN) was selected and applied to a clinical scenario which was instantiated as a prototype in a Service Oriented Architecture (SOA) framework.

Results:

The proposed approach is confirmed as sufficiently powerful to represent clinical workflow in a formal model and execute the workflow in computer mediated decision support. This approach encourages guideline formation and rapid expert review/update while shortening the guideline modelling – execution gap by substantially obviating the need for code writing and largely dispensing with platform dependencies.

Discussion:

Formal modelling approaches are increasingly being used in clinical guidelines not just as development aids but also to support formal semantics and knowledge transfer. These new forms of representation provide a better abstraction for domain experts and users. We show, using BPMN modelling (which separates domain knowledge from implementation), how to create a higher level health-specific modelling representation and execute the model through automated mapping.

Keywords:

DSS, clinical guidelines, design science.

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Background:

Review of difficulties experienced with proprietary guidelines languages and in clinical decision support has led us to the development of a Decision Support System (DSS) based on SOA using Web Services and BPEL (Morrison, 2006). We used (i) Web Services as a delivery mechanism and noted it have the potential to reduce the complexity of interconnecting heterogeneous clinical software systems by providing a level of service and information flow abstraction and (ii) BPEL as a coordination mechanism to orchestrate Web Services execution required to assist decision making in a clinical context.

In the example we provided at that time, we transformed a narrative asthma prescribing workflow into BPEL. Since the BPEL representation (model) is intended for machine execution, it should be complete and contains all implementation/technical details which are necessary for a workflow engine to understand and execute the representation.

Although BPEL model is useful, discussing a clinical workflow in this low-level textual XML representation with non-technical experts is not an easy task. Numerous BPEL implementations, such as Oracle Process Manager (www.oracle.com/technology/bpel) and ActiveBPEL (http://www.activevos.com/community-open-source.php), have provided visual designing tools in order to provide better readibility and understandibilty. This has the advantage that a BPEL model does not need to be edited at the textual level. However, the notation used is not abstract enough to be applied to problem domain as they are very close to the underlying BPEL constructs.

The use of high level modelling would shift the focus from the technical domain toward the concepts of the problem domain. Reducing the distance between problem domain and representation would allow a more readable and understandable model and encourage discussion between guideline engineers and clinical experts. This can form the basis for transferable and re-usable clinical models provided domain-level representations of key processes and information can be rendered to specific application.

This paper discusses the use of a visual modelling language to transform clinical workflow to executable guidelines by means of an automated mapping.

Methods:

The design-science is a technology oriented paradigm that has its roots in engineering and the sciences of the artificial (Simon, 1996). Whereas natural science tries to understand reality, design science attempts to create things to meet certain desired goals. Its products are assessed against criteria of value or utility: Does it work? Is it an improvement? (March, 1995).

Generally accepted activities in design science are: Build and Evaluate (March, 1995; Hevner, 2004). Build is the process of constructing an artifact to meet specific goals while Evaluate concerns with how well they achieve the purpose. Typical results in design science include construct, model, method, and instantiation (March, 1995).

Prior building, we reviewed Business Process Modelling Notation (BPMN), Unified Modelling Language (UML) and XML Process Description Language (XPDL) as these three languages have been considered to have adequate support for workflow modelling required in clinical settings (van der Aalst, 2003; Lang, 2006). Based on our hands-on experience, we selected BPMN for its diagram simplicity and clearness, formalization, native support for Web Services invocation, and availability of workflow engines.

We constructed mapping between clinical processes and BPMN in Build phase. As expected this mapping is quite straighforward. For example process, sub-process, and task may be used to model clinical activity (work needs to be done), gateway for various clinical decision points and pool and lane for clinical roles (e.g. patient, GP, EHR).

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In evaluation, we demonstrate our approach utility with focus to asthma prescribing guidelines (Liaw, 2004). To model this guideline, we first selected an asthma use case and its associated clinical processes. Then we mapped the processes to BPMN following the asthma guidelines. This model then transformed into BPEL for execution.

Result:

Following the design science activities described above, some design artifacts were produced: (i) model describing mapping from clinical process into BPMN (ii) a BPMN model for a subset of asthma guidelines and (iii) instantiation of the asthma model (prototype) where the model in BPMN was transformed into BPEL scripts and executed in a workflow engine for enactment.

The asthma model captured the "Examination" process where GP initiates the workflow and sends an examination request to Practice Nurse. Having received the result from the Nurse, the workflow then accesses EHR to retrieve last visit examination's result for a particular patient. Upon execution, the prototype coordinated activities to provide support for GP decision making in the context of asthma prescribing through activation of a set of participants such as GP, Practice Nurse and clinical resources such as Electronic Health Record (EHR).

For BPMN modellling and execution, we used the Intalio Designer and BPMS Server (www.intalio.com). We used a simplified version of General Practice Data Model for EHR which was implemented as a Web Service developed using Java (http://java.sun.com) and deployed in Tomcat (http://tomcat.apache.org).

Although this is not a complete representation in executable form of all the clinical process in the asthma guideline, we believe this is sufficient to demonstrate the approach for turning such clinical workflow descriptions into computer-coordinated service exchanges and human-computer interactions to support decision making.

Discussion:

On BPMN, XPDL and UML

In previous reseach, we used BPEL to execute clinical workflow. While BPEL served its purpose well as an execution language, the model was less readable and less understandable by domain experts as it contained complete implementation details. Visual and higher level languages would encourage more discussions with domain expert as they provide a better abstraction from implementation details and therefore provide better readability and understandibility.

In the literature several visual clinical modelling languages (e.g. GLIF, Proforma, SAGE) have been proposed. From control-flow perspective, these clinical languages are remarkably close to (mainstream) modelling languages (Mulyar, 2007) and several research had adopted these mainstream languages to model clinical workflow. For example, Knape (2003) used UML to model diabetes workflow while Peleg (2004) used Petri Net.

BPMN, as one of many workflow modelling languages currently available, is a graphical notation for drawing business process. One goal of BPMN is to provide generation of BPEL to allow execution. Thus BPMN acts a bridge between process design and implementation. Although BPEL generation is supported internally, there are few cases where mapping from BPMN to BPEL proves to be difficult (Ouyang, 2005). This is understandable as they both belong to different classes of modelling languages. While BPMN is a graph-oriented language, BPEL is mainly block-oriented language. Workaround for this problems have been proposed (Dumas, 2007).

Although designed as a process interchange standard, XPDL has been used to model workflow and there exists some XPDL-compatible workflow engines (such as Enhydra Shark). At the time of the review, the currently available Enhydra Shark had not yet fully integrated Web Services. For example, passing complex schema type to/from Web Services was still not currently supported.

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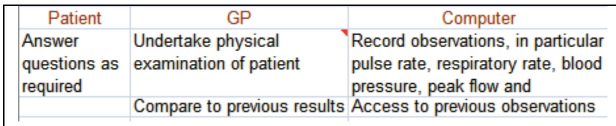
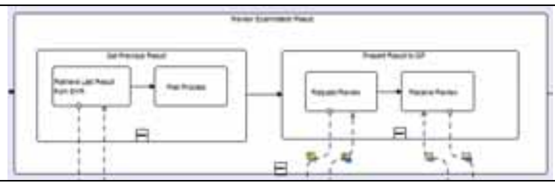
UML is a de facto modeling language to visualize, specify, construct and document software-intensive systems. To address the more specific aspects of a particular domain, the UML needs to be specialized and extended. For this purpose, the standard foresees the extension mechanism of profiles. Several UML profiles have been created to provide automatic mapping from UML to BPEL (see for example Amsden, 2003; Skogan, 2004; Anzbock, 2005). However these profiles so far indicate that it is not yet possible to use UML to model a workflow at a complex domain level in health care as constructs in the profile resemble their low-level counterparts in BPEL.

Reflections of on using BPMN for clinical modelling

By using BPMN, our asthma guideline is now both descriptive and executable. Descriptive because the model is now more readable and more understandable (compared to its representation in BPEL) to clinical experts. Executable as the BPMN model now can be executed almost instantly via automated mapping to BPEL. We noticed that this removes the need for code writing while shortening the guideline modelling – execution gap.



Patient	GP	Computer
Answer questions as required	Undertake physical examination of patient	Record observations, in particular pulse rate, respiratory rate, blood pressure, peak flow and
	Compare to previous results	Access to previous observations



Descriptive model	BPMN model

In our experience, it is almost one-on-one mapping between "Examination" in asthma guideline and its BPMN model (see above figure). This natural mapping encourages more active discussion between guidelines engineers and clinical experts and, in turn, would facilitate guideline formation and rapid expert review/update.

Nested process in BPMN provides a flexible way of structuring a process. Although it is possible to model "Examination" process in a flat view, we opted to adopt a top down approach in which the top level diagram shows the whole process on a single page and uses sub processes to expand details as necessary.

By design, BPMN decouples domain knowledge from implementation. However, sometimes "internal operations" (variables manipulation, manual tasks, etc) must be performed. For example, presenting a user (human) task involves two tasks as required by current Intalio Designer. Using sub process, we could hide this detail implementation and thus further encourage separation of knowledge and implementation.

Developing clinical guidelines is an expensive task and time consuming. Therefore reusing guidelines should be encouraged (Peleg, 2005; Kawamoto, 2005). In support of their optimism, our approach also enables a clinical process to be re-used in different context (use case). For example, "Examination" process can be used in "Child Acute Asthma Encounter" and "Adult Chronic Asthma Encounter" use cases provided necessary information model have been anticipated.

Conclusion:

We show how to represent clinical workflow using BPMN and execute the model via automated mapping. This approach encourages guidelines formation, rapid update, reuse while shortening the modelling and execution gap. Although this paper focused on one specific application (asthma guidelines), the proposed approach supports scalability and generalization.

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