Ontology-Driven Cardiovascular Decision Support System

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Abstract

We discuss work-in-progress and propose an ontology driven framework for the development of a clinical expert system for chest pain risk assessment. The framework has the following key components: adaptive questionnaire, patient medical history, risk assessment and decision support. We intend to incorporate a range of chest pain assessment guidelines and risk scoring rules within the system and design the framework so it can be extended to a range of other cardiovascular diseases in various clinical settings.

Keywords: Decision Support System; Ontology

1 Introduction

Patients who present with chest pain continue to present a major diagnostic challenge for both primary and secondary care physicians. This is due, in part, to the low specificity of chest pain as a symptom of significant coronary artery disease and the danger of misdiagnosis in patients at risk of major cardiac events. Furthermore, chest pain is a very common symptom among the general population and a common presenting complaint in patients attending Accident and Emergency department [9].

The rest of the paper is organized as follows: Section 2 presents some background information on chest pain and the technological need in improved Clinical Decision Support System (CDSS) tools. Section 3 discuss our proposed ontology-driven framework development. Section 4 presents the application of the framework for chest pain assessment and we conclude in section 5.

2 Background

In a primary care setting, General Practitioners (GP) often refer patients with suspected cardiac chest pain to a Rapid Access Chest Pain Clinics (RACPC) in Secondary care which are often nurse-led clinics. These clinics were designed to allow direct access to cardiology expertise without the need for accident and emergency assessment or admission to a medical ward [8]. The RACPC service only accepts referrals where certain medical conditions are met to ensure the patients suitability for these clinics. Information management systems within these clinics are not centralized and very much paper based. The patients full medical history is not available at the time of assessment, for either of primary and secondary care clinicians. This present clinicians with a challenge in order to make the correct medical diagnosis for each specific patients.

Thus, the following issues can be identified for managing the underlying risks associated with chest pain:

1. a lack of adaptive, intelligent patient clinical information gathering systems that enable collating all the relevant medical history of patients.

2. as a result, clinicians can make referrals errors. This could either lead to unnecessary referral to secondary care or – on the other hand – an unmet care need by leaving the patients at risk of complications or adverse events if a prompt referral is not made.

3. a lack of availability of the patient's medical history (cardio-vascular (CV) and family history) and cardiac risk scores for the assessment of heart conditions such as chest pain.

4. in conventional healthcare systems, patients are sometimes insufficiently involved in the decision making process. An IT healthcare systems should strive to work *with* the patients instead of working *for* the patients.

3 Ontology-Driven Framework

3.1 Dynamic Questionnaire

A previous study concluded that face-to-face information collection with a clinician is often less complete than computer-based history taking [10]. The first phase in this

project is to develop an ontology driven adaptive questionnaire for CV screening using standardized questionnaires for CV and family history acquired from Harvard medical school, which agreed to provide access to the standardized questionnaires for the overall screening of patients for all the major diseases. The questionnaire will be divided into two categories: cardiovascular and family History, as per the recommendations of NICE (National Institute of Clinical Excellence) guidelines. The purpose of this context-sensitive adaptive questionnaire is to mimic the exploratory behavior exhibited by the clinicians as reported in [1, 2].

These questionnaires will be customized to suite the local UK context. The main challenge is to have an intelligent questionnaire which adapts itself as per patient's medical history thus only asking relevant information which is pertinent to patient's circumstances. Ontology driven approach will help us achieve the performance and scalability in our proposed system by reducing number of questions therefore making doctor-patient interaction much more interesting and cost effective. The questionnaire will be organised along semantic partitions and as per the guidelines of existing biomedical Ontologies like SNOMED CT[1]. The questionnaire ontology is presently being developed using the Protégé ontology editor [2] and OWL (Web Ontology language) is used for the development of dedicated Ontologies required to implement the proposed clinical decision support framework.

3.2 Semantic Patient Profile

In conventional distributed database (DB) systems, patient data held in the database are not routinely explicitly associated with specific intrinsic semantic meaning, i.e. outside of the data record itself. Patient data is often complex and diverse, often in different formats, reside in heterogeneous structures and carry different meanings. This makes the comparison, data mining and analysis of clinical data a challenging task. Many healthcare applications envisage patient data without integrating additional semantic information necessary for structure and analysis of the data. This data cannot be used or integrated with other third party health software applications without costly software engineering work which, can often cause deployment delays and application downtimes. We propose to use a semantic patient profile development approach previously reported in [2, 3]. The information collection based on an ontology creates the opportunity to simultaneously generate a patient profile, automatically generated from a medical ontology. This method permits to preserve the semantics of the patients' clinical data. The main advantage of the approach

is that a single information repository: *a semantic patient medical profile*, can then provide access to various services and third party APIs. This will enable us to store data in a dedicated repository, as input to a rule engine, a clinical document or a patient record for clinicians use for assessments as reported in [4] and as illustrated in Fig. 1.
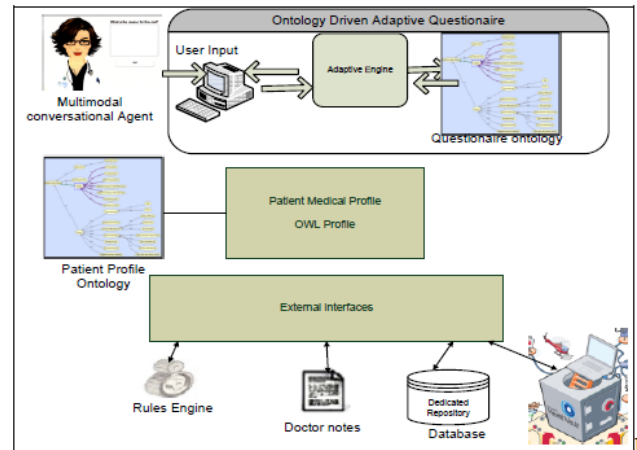
Figure 1. Proposed framework: Adaptive questionnaire and Patient Medical Profile as reported in [2, 3]

This system design provides greater flexibility as new software components can be included and redundant one discarded without affecting the whole structure of the system. Profile heterogeneity is currently being considered and, in order to make it compatible with other clinical information management systems, we are considering a process of mapping the concepts in the patient ontology to the SNOMED CT terminology. Patient semantic profile ontology is currently being developed using answers acquired through adaptive questionnaires. The items of information which are relevant to clinicians consist of Boolean-type questions regarding a patient's medical history. The presence or absence of specific medical condition is represented in OWL format. Example, *"has the patient got chest pain?"*, *"is the patient a smoker?"*. For this type of information, modeling is done through the use of the *"hasPresence* and *"hasAbsence"* functional properties as reported in [2, 3].

4 Chest Pain Assessment

The proposed system architecture of the chest pain decision support is shown in Fig. 2. The main components of the system are:

4.1 User Interface

In the first system iteration, patients and clinicians will be provided with text-enabled user interfaces (UIs) which will be available online, running from centralized servers. There will be two different entry points / UIs for clinicians and patients. The access to these interfaces will be granted based on role. Patients will only be able to access patient's interface and will not be able to gain access to the clinicians' portal.

The Patient interface: This will allow patients to take CV and family history interview in their homes at the time of convenience, prior to their appointment with primary care doctor (Cardiologist in US and GP in UK context).

The Clinician Interface: At the time of the patient's appointment with the GP, the summary or the clinical notes will be available to clinicians (both primary and secondary care) through clinicians' interface which will be username and password protected for security and data protection purposes. This will be a cost effective way of generating patient's medical history and make it available for clinicians which they often lack at the time of consultations.
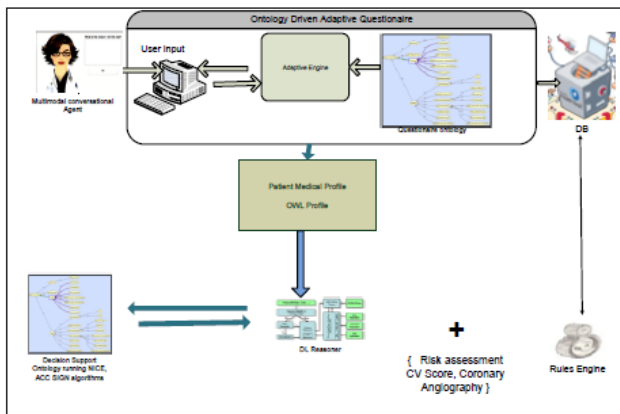

Figure 2. Chest pain CDSS

4.2 Knowledge Adaptation & Data Repository

As discussed earlier, context-sensitive information will be collected using dynamic questionnaire modules. Patients will be asked to fill a pre-appointment assessment online. The adaptive questionnaire will be driven through the ontology thus creating a dedicated layer of abstraction for ease of use, maintenance and deployment purposes. There will be

explicit separation among core system functionalities and the domain expert's knowledge-base used by the decision support system. This means that the questionnaire ontology can be updated with limited software engineering work as suggested in [4, 5]. This system will enable clinicians to view the results of these questionnaires and benefit from the snapshot of patients medical histories for the assessment.

Patients' medical histories will be stored in a dedicated DB repository to calculate CV risk score using Framingham[3] and Assign[4] risk score calculators. This data will also be used for statistical analysis, data mining and generating electronic health records for the patients.

4.3 Chest Pain Classification, Clinical Rules & Decision Support Ontology

There is a strong clinical case for choosing to run different chest pain assessment guidelines depending on the specifics of a patient or a particular procedure. Chest pain classification will be carried out using NICE, ACC (American College of Cardiology) and SIGN (Scottish Intercollegiate Guidelines Network) guidelines. Clinicians will be able to select risk assessment standard of their choice for carrying out chest pain risk assessment and classification of patients. The classification of the patients with suspected angina will be carried out using a dynamic logic reasoner.

The decision support ontology will be peer reviewed by a consultant cardiologist in the U.K. The purpose of the decision support system is to support primary care and secondary care clinicians by providing them with functionalities to select a risk assessment tool of their choice (as per the geographical and clinical needs) from multiple risk assessment guidelines. This will be one of the unique features of the decision support framework, which will make it possible for the healthcare service providers to deploy this clinical decision support system in different healthcare settings in the U.K. and U.S. The decision support Ontology will consist of Risk assessment Ontology, a Recommended Lab Test ontology and a Prescribing ontology. The role of the risk assessment ontology is to calculate risk score (Cardiac risk score index using Framingham and Assign risk Score algorithms). It will also be used to assess whether patients belong to different chest pain categories for coronary angiography treatments in line with the clinical pathway set out in RACPC guidelines.

The decision support ontology will perform the following operations: Risk assessment, Recommended Test & Prescribing Ontology. The purpose of risk assessment is to highlight potential risks and complications given a pa-

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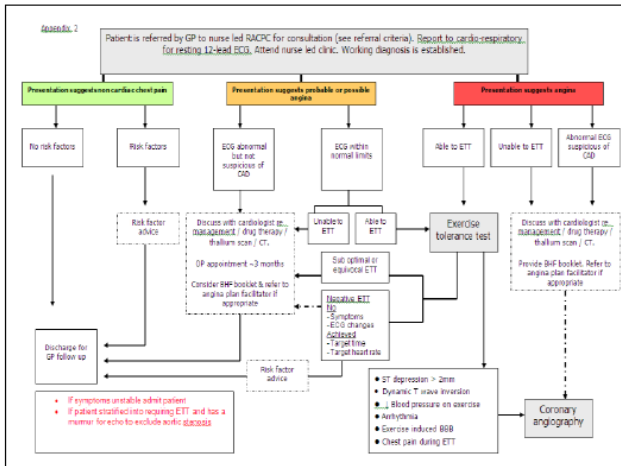
[3]http://www.mdcalc.com/framingham/cardiac-risk-score

[4]http://assign-score.com/estimate-the-risk/calculation-format/

Figure 3. RACPC Clinical Pathway

tient semantic profile. The "Recommended Test" Ontology is being developed to suggest certain lab tests which may further help to decide whether patient is suitable for a particular treatment: e.g. coronary angiography. This ontology will be used to prescribe specific tests as per the chest pain classification and risk assessment of the patients. A similar approach is described in [6, 7]

These tests include Drug therapy, Thallium Scan and CT (Computer Tomography) scan. In certain scenarios patients will be referred back to GP or Cardiologist for further follow up. The Prescribing Ontology will be used to suggest possible drugs to treat the patients based on their risk assessment and clinical pathway results.

5 Conclusion & Future work

We have presented a proposed ontology driven framework for the development of a cardiovascular decision support system focusing on chest pain risk assessment. In our experience, existing services are often paper-based and led by cardiology nurses. The framework will facilitate the automation of RACPC service. The proposed system could be used to support existing RACPC services in selected cardiology clinics in UK and provide electronic support to conventional paper based clinics.

We argue that the main advantages of the ontology driven approach are as follows: cost-effective maintenance of the CDSS due to a clear demarcation among the knowledgebase and decision support functions. The ontology layer should enable the system to perform decision support operations which are not routinely implemented in existing distributed system and databases technologies. The approach should also facilitate reuse and extension of the CDSS to include other diseases in the cardiovascular domain.

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