@neurIST – Chronic Disease Management through Integration of Heterogeneous Data and Computer-interpretable Guideline Services

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Abstract. This paper presents an overview of computerised decision support for clinical practice. The concept of computer-interpretable guidelines is introduced in the context of the @neurIST project, which aims at supporting the research and treatment of asymptomatic unruptured cerebral aneurysms by bringing together heterogeneous data, computing and complex processing services. The architecture is generic enough to adapt it to the treatment of other diseases beyond cerebral aneurysms. The paper reviews the generic requirements of the @neurIST system and presents the innovative work in distributing executable clinical guidelines.

Introduction

In healthcare, the case for computerised decision support (CDS) is now widely accepted. It is part of the wider case for healthcare IT. Several countries have published or are implementing national healthcare IT programmes, including the UK, Canada, Denmark, Finland, France, Hungary, New Zealand and the USA [1].

While the details vary, the trend is clear – investment is increasing in healthcare IT. Improved IT infrastructures are creating a platform for CDS. Now the full potential of CDS can be seriously considered.

This paper reviews the different levels of CDS. Attention is drawn to the use of computer-interpretable guidelines, which represent the most sophisticated type of CDS.
These executable guidelines are developed in a formal clinical guideline modelling language, and then executed via an inference engine.

The @neurIST European Integrated Project is implementing executable guidelines within the context of High Performance Computing. The @neurIST Project and the architecture of the system have been described elsewhere [2]. In summary, the project is focused on asymptomatic cerebral aneurysms as a paradigm for complex risk assessment and treatment planning. Clinical data is being integrated from multiple sources via CDS to provide patient-specific rupture risk assessment and treatment recommendations. This paper highlights the challenges for CDS that need to be overcome for the integration of heterogeneous data and computing resources, and to enable risk assessment and treatment planning procedures. The implications for regional and national CDS implementations are discussed.

1. Computerised Decision Support

For CDS to be cost-effective, it must address the disadvantages caused by disjointed and disconnected healthcare systems, such as inefficiencies, errors, delays and inconsistencies of care. These have significant cost and quality implications at a time when global healthcare spending is projected to escalate significantly over the next 15 years.

Specifically, CDS must address:

- **Variations in clinical practice.** It takes at least 5 years for recommendations in published guidelines to become part of routine practice. Even when guidelines are broadly accepted, recommendations may still not be followed. On the other hand, patients and families are increasingly aware of the latest options. They want the best but they also want to have choice. Standardised ‘cook book’ medicine is not appropriate.

- **Burden of chronic disease.** The costs of healthcare are not distributed evenly. The Center for Medicare and Medicaid Services (CMS) has estimated that 1% of patients consume at least 25% of healthcare expenditure, with 70% of expenditure being used to treat 10% of patients. These patients have complex chronic diseases, often with multiple co-morbidities, resulting in complicated – and hence expensive – disease management issues.

- **Costs of medical errors.** There is growing concern about the cost of medical errors as highlighted by the recent report of the US National Committee for Quality Assurance [3].

1.1. Levels of CDS

Initially, clinical practice guidelines (CPGs) were developed to improve care. CPGs are systematically developed statements that assist practitioners to provide appropriate evidence-based care. Most CPGs are text-based, existing in paper-form, or electronically as PDF documents for example. CPGs can improve outcomes but their use in chronic diseases with multiple co-morbidities is limited by problems of information overload [4].

CDS offers the potential to reduce the information burden. For the purposes of this paper, three levels of CDS can be defined:
• **Information support.** Narrative text is presented to the user via html web pages for example. Content is not automatically customized to the individual patient. The clinical user must navigate information and ascertain what, if any, content is relevant. This type of CDS is also known as “passive” decision support.

• **Action rules.** These are typically implemented as single step “if… then…” rules, often associated with clinical alerts. Content can be customized to the individual patient but the breadth of content is extremely limited.

• **Computer-Interpretable Guidelines (CIGs).** Guideline content is customized to individual patients, hence the description “active” decision support. Guidelines can be linked, enabling guidelines for patients who have chronic diseases with multiple co-morbidities.

CIGs have the following characteristics:

• **Formal guideline representation language,** which enables clinical guideline content to be represented in a formal computer-executable syntax. Examples include PROforma and GLIF.

• **Authoring tool,** for creating the executable content using the guideline representation language.

• **Inference engine,** for executing CIG content at run-time.

Depending on the implementation, CIGs may include references to external ontologies, terminology services, and clinical data from electronic health records.

2. **Improving clinical outcomes with CDS**

Research suggests that not all levels of CDS improve clinical practice. Kawamoto *et al.* [5] conducted a systematic review of randomised controlled trials involving computerised decision support. They found that decision support systems improved clinical practice in 68% of trials. This figure improved to 94% if the systems incorporated all of the following features (in descending order of relative efficacy):

• Automatic decision support as part of clinician workflow

• Provision of recommendations rather than just assessments

• Provision of decision support at the time and location of decision-making

• Computer-based decision support

Garg *et al.* [6] systematically reviewed effects of computerised CDS on practitioner performance and found that:

• CDS improved practitioner performance in 64% of studies

• Practitioner performance improved 73% with CDS solutions automatically prompting users compared with only 47% improvement for systems required to be activated by the user.

3. **Distributed CDS Solution**

When the @neurIST project was conceived, it was recognised that the FEA and CFD analysis requirements would require High Performance Computing. There was no similar expectation for the CDS service. Although the risk assessment and treatment
CIG requires output variables from the @neuCompute service, the CIG is not responsible for providing FEA and CFD analysis. The CDS knowledge base files are tiny by comparison to the data files required for FEA and CFD. Furthermore, the size and processing speed of the inference engine did not warrant High Performance Computing for the processing of single CIG instance.

Within any specialist centre that manages patients with asymptomatic cerebral aneurysms, the number of cases requiring CDS would be very small at any one time. Therefore the number of calls to the CDS service would be very low. Existing implementations of CIGs as Web services in healthcare regions in Europe and in one roll-out nationally (New Zealand), have demonstrated that simultaneous calls on CDS services are rare. These implementations have been directed at family physician practices and have covered a wide range of acute and chronic diseases. The extension of CIG services into hospitals significantly increases the number of calls on the services. One healthcare region has calculated that a CIG service for a population base of 1.5 million people would generate 2,000 simultaneous CIGs.

The potential high use of CIGs prompted a review of how the @neurIST architecture might support massive parallel processing of CIGs. The CIG inference engine has been enabled as a SOA Web service. Experiments have been conducted using the @neuCompute developments. The inference engine and the CIG knowledge base files have been distributed. CIGs have been successfully called and executed.

This development has opened up a new set of requirements. Given that chronic disease management requires monitoring patients across multiple geographic sites, the relevant clinical data is distributed in different databases. If clinical databases were federated, then CIG CDS services could request relevant data from multiple sources when processing a CIG. The aneurysm-specific example would be a patient who was diagnosed incidentally from a CT head scan performed in a secondary referral centre. When the patient was referred to the tertiary specialist service for risk assessment, @neuRisk could call clinical data from the referral centre and from the family physician’s electronic medical record.

Clinical databases are heterogeneous. CIGs content has to be developed in a standardised way. The content cannot be written to comply with the data representations in multiple databases. In addition to the @neuInfo innovations in support of the research component of @neurIST, work has begun on defining a virtual medical record (vMR) for CDS. The vMR Project has now been formally accepted by HL7 International and is being delivered according to the HL7 Development Framework. The vMR is defining how data inputs and outputs from a CDS service can be represented according to the HL7 Reference Information Model. A standardised vMR will then open up the possibility of creating an HL7-compliant CIG representation language meta-model. Given that the HL7 Reference Information Model is UML-compliant, there is also the possibility of using the Object Constraint Language as a mechanism for querying a vMR. Further work is planned in this regard, particularly with respect to integration into the @neurIST middleware layer and into the security framework.
4. Discussion and Conclusions

In this paper we present various levels of computerised decision support, including computer-interpretable guidelines which have proven effectiveness in delivering improved patient care. The use of executable clinical guidelines was reviewed in the context of the @neurIST Project, which provides applications and services to help in the research and clinical treatment of aneurysms. The @neurIST architecture is utilizing High Performance Computing for complex EFA and CFD simulations. Although individual executable clinical guidelines have minimal computing requirements, regional and national implementations for acute and chronic diseases suggest that there will be high demand for guidelines in any given region as the content is extended into other clinical domains. The @neurIST project has been used to distribute a SOA-enabled inference engine and executable guidelines. This has provided the impetus to create an international standard for messaging clinical data between heterogeneous databases and distributed computer decision support services. This standard will be based on the HL7 Reference Information Model, which has raised the possibility of using the Object Constraint Language for interrogating data sources that are HL7 v.3 compliant.

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References