An Architecture to Support Ultrasound Report Generation and Standardisation

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Keywords: Ultrasound, Ultrasound Reporting, Ontology, Radiology, Digital Healthcare

Abstract: Ultrasound reports are developed in different ways by clinicians and radiologists. These variations in reporting style, content and format could impact on the value of the report and the way it is interpreted, which in turn have implications on patient management and decision making. There are many reasons for the poor success rate of some reporting systems which is usually down to poor adaptability and the main one being the human factor. In this paper, we present a system architecture model for a proposed medical ultrasound reporting system that attempt to address some of these problems. In this system, we propose a solution where humans will not need to adapt to the system, instead the system acknowledge the various styles, contents and format being produced by the humans and uses an ontology to standardise the terminology and Natural Language Processing techniques to transform free text reports to the preferred proposed model of a structured and standardised report.

1 INTRODUCTION

Medical ultrasound reports are the main tool for communicating the result of an ultrasound examination from a sonographer or radiologist to a referring clinician. Ultrasound images alone are of limited value since the outcomes of any ultrasound investigation are based on the findings during the scan (Boland, 2007). The ultrasound report therefore can be considered as a vital part in diagnosing a patient because of the way the ultrasound examination is performed.

Tissues characterisation alongside quantitative measurements, are features typically reported on during the scan (Sluis and Mankovich, 2002). The amount of data therefore obtained during the examination is huge. Variations in reporting styles vary widely; this leads to variations in the structure of reports as well as in the terminologies used. These variations may impact on the way a report is interpreted and in turn affect the decision making process and the way a patient is managed.

According to Kahn et al. (2009), the industry believes that the solution to this problem resides in using structured reporting with the support of ontology as its knowledge base. There are several benefits, including inserting measurements and key images in reports (Sluis and Mankovich, 2002). This in turn makes it easier to perform estimations and aids in decision making. Structured reporting has been shown to improve the accuracy of reports (Bosmans et al., 2012) since the reports produced incorporate standardised terms.

Compared to free-form text, data from structured reporting can be easily queried and populated. Structured reporting also increases the accessibility of data for research. Furthermore, structured reporting gives the ability to improve the quality of a medical report since individual elements measuring quality are more easily defined (Schwartz, et al., 2011).

It is known that in medical and healthcare disciplines, there are a significant number of terminologies being used. To add to that, several terminologies are often used to describe the same condition. For example, carcinoma and cancer, calculi and stone, as well as neoplasm and tumour are both different words that have the same meaning.

The development of ontology allows for these terminologies with commonly accepted definitions to be sorted in a dictionary similar to a framework for knowledge representation (Smith, 2003). It defines a common vocabulary of machine-interpretable definitions of basic concepts in the domain and the relations among them (Noy & McGuinness, 2001). With the existence of ontologies, it is possible to annotate terms published on the internet to allow computers to query and extract relevant information pertaining to a concept even though it uses different terms. In our case, the use of an ontology will allow for standardization of terminologies used in ultrasound reports.

For a better exploitation and use of these reports, computerised tools that can facilitate these processes need also to be developed. In this paper, we describe the architecture of a software system that is designed to support the standardisation of the process of generating ultrasound images reports.

The remainder of the paper is organised as follows; in section 2 we review the literature and identify related works and research. Section 3 will explain the proposed architecture model before we conclude the paper in section 4.

2 RELATED WORK

Realising the effectiveness of conveying information in structured forms, several researchers have developed models and proposals to apply structured reporting as a method to create radiology and ultrasound reports (Bell, Greenes and Doubilet, 1992; Kuhn et al., 1993). The early structured reporting systems were constructed using checkboxes and radio buttons for the radiologists to choose concepts from a list of terminologies (Bell et al., 1992). These checkboxes and radio buttons were used to answer a set of predefined questions to develop the content of the report. One disadvantage of this approach is that it limits the inclusion of additional information that could be important for the case, and would not allow the form to be submitted with certain fields being left blank. These options are important as sometimes reports may contain more information than the predefined one and in some instances some information cannot be obtained.

In previous studies (Naik, Hanbidge & Wilson, 2001; Johnson, et al., 2009; Plumb, Grieve & Khan, 2009) attempts were made to identify the radiologists preferences when creating reports. As a result, it is shown that both radiologists and referring clinicians prefer structured reporting over other methods of reporting. Whilst this type of system has been used in some Radiology Departments (Bell and Greenes, 1994), there are challenges which have limited it to wider implementation

Radiologists found that the implementation of structured reporting systems was time consuming and overly constrained where it did not allow them to include more content than what the system asked for (Johnson et al., 2009; Langlotz, 2009). Structured reporting is also seen as interference during the image interpretation process (Bosmans et al., 2012; Weiss and Langlotz, 2008) and does not give any productivity advantage to the radiologist.

In a recent study conducted by Bosmans et al. (2012), radiologists were convinced that a structured report should allow for free-form remarks to allow for reflections or expression of uncertainty. This is important because different cases would have different observations and would need to include different types of information. It is also important for a structured report to allow for certain information to be left out but with some remarks explaining the reason (United Kingdom Association of Sonographers (UKAS), 2008), because not all information can always be obtained due to limitations often encountered during the scan process. Structured reporting would be readily accepted by radiologists if it is more flexible whereby they would be able to choose what to include and what to leave out in the report depending on the case that is being reported. This flexibility is the main characteristic that we would like to incorporate in our proposed model together with standardisation.

Ontologies serve several purposes in the medical field. This is proven by the existence of many medical related ontologies such as Foundational Model of Anatomy (FMA), Systematized Nomenclature of Medicine - Clinical Terms (SNOMED CT) and Radiology Lexicon (RadLex) (Rubin, 2008). One of the main purposes of an ontology in radiology domain is to annotate images and reports. Radiology departments, produce thousands of images and reports concerning examinations performed on patients. By annotating these images and reports, it is easier for automatically searching and extracting information from these images and integrates them in teaching and research where they can play an important role.

RadiO, a prototype application by Marwede, Fielding, & Kahn (2007) is one example of annotating reports using ontologies. In this application, image features of image entities are annotated using an application ontology of imaging ‘findings’ and their interpretation as a knowledge base. Another example of an application is

Interdisciplinary Prostate Ontology Project (IPOP) (Overton, Romagnoli & Chhem, 2011), which uses ontologies from OBO Foundry to annotate clinical reports about prostate cancer.

Ontology also serves a purpose in report generation such as the one in the MIAKT project (Bontcheva & Wilks, 2004). In this project, reports are generated automatically from knowledge encoded in the domain ontology using Natural Language Generation Techniques (NLG). Semantic data such as patients' information and diagnosis are encoded in the ontology of the breast cancer domain. The role of NLG is to turn these data to textual description in order to generate complete reports. These reports however are in a free-form structure which defies the notion that structured report with the support of ontology is the way to go forward in ultrasound reporting.

Therefore, we propose a model that will give flexibility while at the same time ensuring standardisation in terminologies and reporting styles by applying natural language processing technique and ontology.

3 THE PROPOSED MODEL

The proposed model is designed with the needs of the radiologists and clinicians at the centre of the new system. It is known that humans sometimes have a resistance to change or adapt to new working procedures. In order for them to accept changes it is important for the system to have a level of flexibility and for the practitioners to get involved in the design of the new system. This would help the transition from free-form text reporting to structured reporting without causing too many frustrations and inconveniences.

From the studies done by Bosmans et al. (2012) and Danton (2010) radiologists were found to have problems with not having more options in creating their reports. With that in mind, we designed a model that allows flexibility for the radiologist to choose whichever way they are comfortable with in writing the report but at the same time producing the same result which is a standardized ultrasound report. Figure 1 shows the components of the proposed model. In the following subsections, we describe the different components of the system.

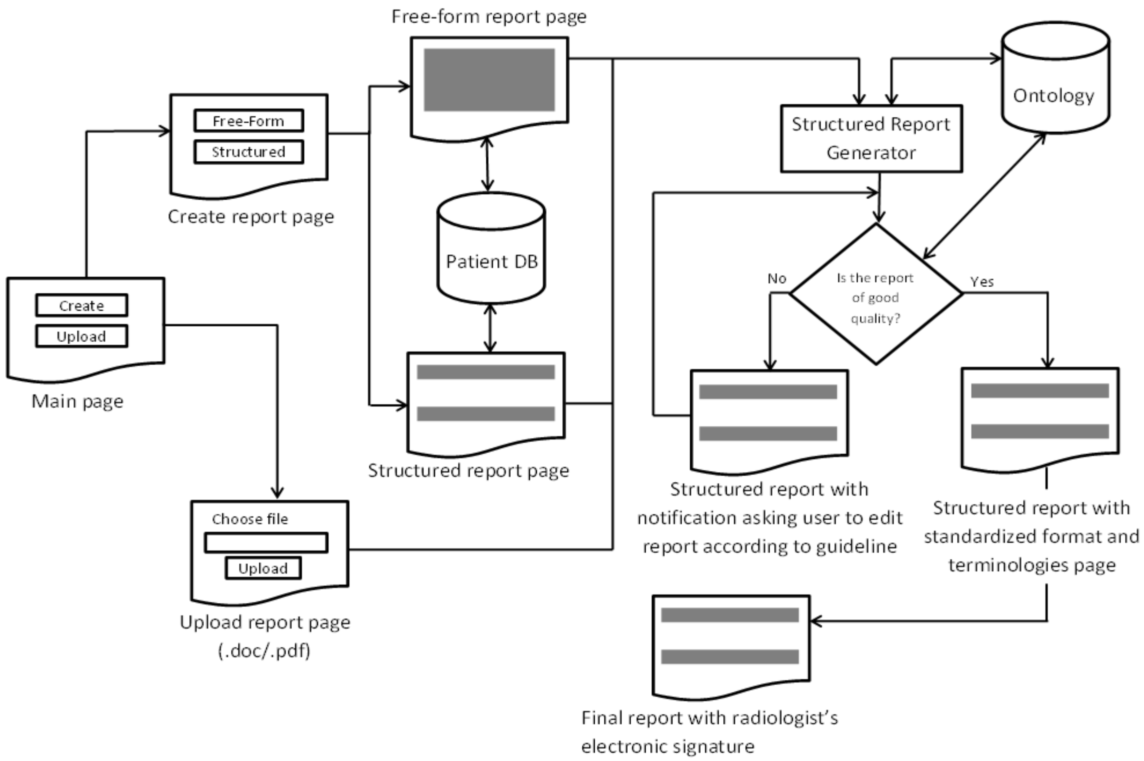

Figure 1: Proposed System Architecture Model of the Reporting System.

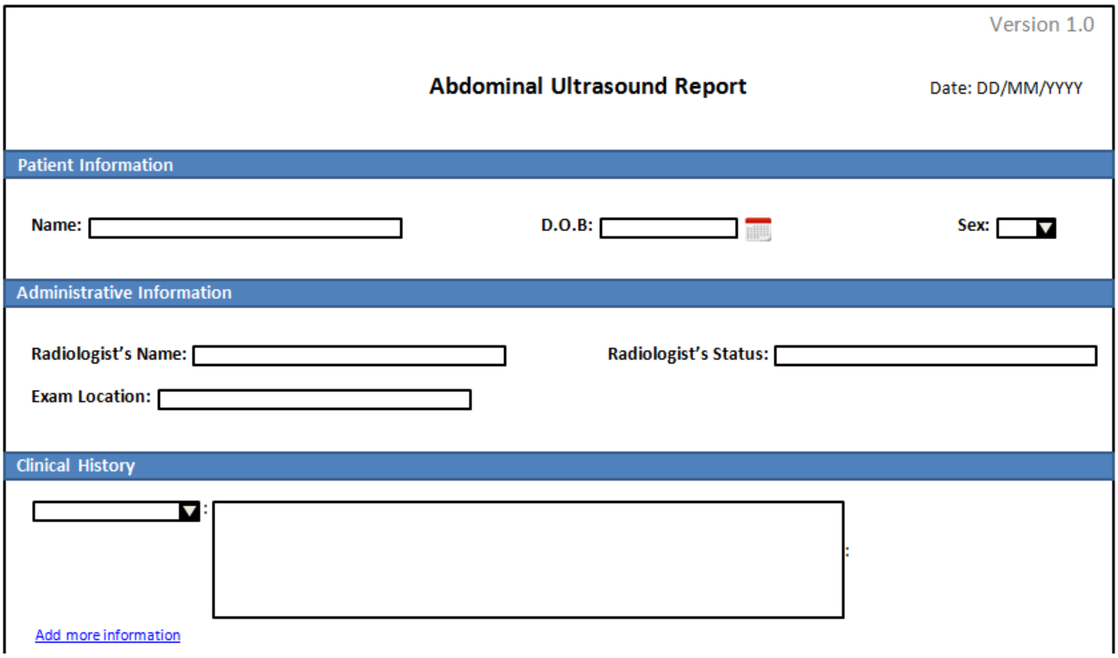

Figure 2: User Interface Design for Structured Report Page.

3.1 The High Level of the System

To allow flexibility, portability and its access from various locations, the system is currently developed as a web-based application. Security and data protection issues are recognised as extremely important and are an integral part of this system. Data protection however is not the main focus of this paper. When logging into the system, there are two options to choose from; (i) create the report using the online form or (ii) upload a report. This offers flexibility as they would not need to stick to one method of writing the report and could use the option that best suit the case they are handling.

3.2 Create Report Page

Once the path to create the ultrasound report using the online form is chosen further options are presented which are using guided free-form or structured report form. Most medical ultrasound reporting system uses a structured form for the radiologist to fill in. This requires a lot of mouse control and clicking. Structured form is also often rigid where it forces the healthcare professional to complete most parts of the form and in this case, the form cannot be submitted until all sections are completed. This could cause frustration to the radiologist and deter their interest in using the system.

In our proposed model, we designed the form to be less rigid compared to the usual structured report form and if they prefer, they can still opt to create reports using the free-form. Both of these forms will be explained further in section 3.2.1 and 3.2.2.

3.2.1 Free-from Report Page

The free-form report page allows the ultrasound report be created by freely typing in their observations without the need to adhere to a certain structure. Creating a report using our system negates the need to provide patient information because the system will automatically link this report to the patient's record.

The free-from report page will consist of three questions related to the ultrasound examination. These questions will act as a guide for report writing. Submission of the report is easily facilitated once the report is complete.

3.2.2 Structured Report Page

In our proposed system, we include a structured report page similar to what was proposed by other researchers (Bell et al., 1992; Kahn, Wang & Bell, 1996). The main difference is that the proposed structured report form will be less rigid compared to the previous ones which allows for a variation in report style.

This can be allowed in our proposed model because all reports that are submitted will need to go through a quality checker before it could be signed off. If the quality checker finds that the report is good enough, it will be accepted. Otherwise, the report will be returned for amendment. This will be further explained in the next sections.

Figure 2 shows a snippet of the user interface design for the structured report page. Similar to the free-form report page, the radiologist will not need the patient's information as this will be automatically included by the system. The same is true for the radiologist's name and status. When the radiologist signs-in to the system, it will automatically display the radiologist's information. In filling in the report, the radiologist will find that the report form is much more flexible compared to other available structured report forms.

For example, under clinical history, the radiologists can choose from the drop-down menu what type of information they would like to include. If they wish, they could add more information by clicking on the 'add more information' link. This allows the radiologist to give as much information as they want in the report.

Though this form still requires a lot of mouse control and clicking, the radiologist will always have the option of using free-from report if they find it hard to fill the structured one. The benefits of using a structured report form is that it would help guide the radiologist in giving enough information about the ultrasound examination and ensure that the report they produce will be rated as being of a good quality report by the report quality checker. This reduces the probability of them needing to edit the report to conform to the quality guidelines

3.3 Upload Report Page

Another option that the radiologists have in creating a standard ultrasound report is by uploading a report that they have written elsewhere. The report could be in formats such as .doc and .pdf and could be written in any way that they prefer. This option is not only for reports that have been recently written. The radiologist could use this option to upload a free-form report that has been written before in order to convert it into a standard form. However, this will depend on the amount of information available in the report. If the report does not contain enough information and is regarded as a low quality report, the generator will not allow for it to be signed off.

3.4 Structured Report Generator

Whether the radiologists choose to create the report using our proposed system or by uploading reports they have created elsewhere, the report will go through a structured report generator which will transform the report into a standardised report. The structured report generator uses domain ontology as its knowledge base. The ontology will consist of thousands of medical terms commonly used in medical ultrasound reports and will be developed by reusing terminologies in existing ontologies such as FMA, SNOMED CT and RadLex. The ontology will help the system to understand what is written in the report and will use that information to ensure standard and consistent terminologies are being used.

The transformation of free-from to structured form will be done using the computational linguistic approach of Rhetorical Structure Theory (RST) which is a descriptive theory of a major aspect of organisation of natural text (William & Thompson, 1988). It allows for the classification of a chunk of texts and the description of relations between two chunks of texts in the free-form report. This will then serve as the information needed to fill in the structured form.

Before the structured report can be displayed to the radiologist, it will go through a quality checker in order to ensure that the report meets the standard quality measure. The quality checker will also use the ontology as its knowledge base together with a set of quality metrics. If the report meets the minimum requirement of the quality checker, the standardized report will be displayed for the radiologist to check and sign off. If the report does not meet the minimum requirement, a standardised report will be displayed to the radiologists but with notifications to edit the parts of the report that do not meet the guidelines. After changes have been made to meet the minimum quality requirement, then only can it be signed off by the radiologist.

4 CONCLUSIONS

In this paper, we presented a system architecture model for a medical ultrasound reporting system. In this model, we proposed a solution where radiologists are allowed to choose a style of reporting that they are most comfortable with.

Whether the radiologists choose to create their report in free-form or structured form or they choose to upload their report, this system will automatically generate a standardised structured version of the report with the support of a medical ultrasound ontology as its knowledge base. It is anticipated that a standardised report based on domain ontology will improve and enhance the quality of an ultrasound report.

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