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Comprehensive Web-Based Patient Data Collection Systems with Integrated Imaging Functionality

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Abstract. Various data collection systems within modern health care networks comprise what should collectively build a single patient record. The ability to do this is unfortunately complicated by the inclusion of patient imaging data which is generally housed in a disparate PACS system. Often such systems are independently maintained and have no direct communication with Electronic Health Record (EHR) and Patient Information Management Systems (PIMS) platforms.
This work showcases the ability to use a web-based data collection system containing completely customized medical templates for all patients – with an integrated image viewer polling data from a dedicated imaging server to provide a comprehensive patient view for analysis. The use of this integrated platform approach provides a better workflow over legacy systems for use within a clinical and research setting, when reviewing patient records or for analytical purposes.

Keywords: Web-based image tools, comprehensive patient data collection, electronic medical record

1 Introduction

Currently, a multitude of unresolved data collection issues exist, including the variations in measures and standards of health care protocols, different reporting paradigms and personal autocratic or ill informed whims within various clinics [1-4]. As a result we see an increase in expenditures related to data, reduced quality of data (rendering it inaccessible in various instances), loss of research opportunity and poor performance measurements [5]. Ultimately, resultant expenditures continue to be unyielding and monitoring of patient care is drastically affected.

Over the past decade, electronic data collection, on both a local and national scale, has penetrated all levels of the hospital system. For those left behind, initiatives to establish electronic data collection systems are underway [6]. Lack of training to accommodate this transition has created a significant burden on health care providers. Mandatory transparency and increased awareness of the inner workings of our hospitals has resulted in requests for data regarding quality, public health,

performance, and other administrative processes in sometimes an uncoordinated and even conflicting manner.

In addition to these issues, patient imaging data is rarely managed and maintained by the same systems that house health and medical data. Depending on the service provider, there exist several taxonomies for collecting similar data. A single organization will use many different disparate electronic collection systems in order to complete one patient chart (as pieces in one may be missing in the other). This is further complicated by researcher needs, where the requirement of access to multiple data sources will lead to a heterogeneity across fields within these databases, making automated analysis impractical (without time consuming and expensive manual intervention).

1.1 Concerns

We are presented with many concerns that need to be addressed when heterogeneous datasets across multiple systems are used, these include:

- The variations within data collection tools and taxonomies: Validating and viewing the data across these systems can be tedious and often result in erroneous data within the complete electronic patient record. This translates to additional costs and constant monitoring of data to make sure systems are updated simultaneously in order to ensure granularity and consistency.
- Documentation, reporting and data quality issues: These challenges include incomplete clinical documentation, failure to understand coding and performance measurements, dependence on manual data abstraction, and inconsistent policies and practices for using secondary data as a source of quality information [7].
- Increases in service provider staff resource requirements: This often increases in conjunction with reporting requirements due to the differences set by the various requestors of performance and quality data [8].
- The ability to utilize data from existing EMR's in legacy systems.

Clearly, these and other issues had to be considered when building a proper architecture for our solution.

2 Development of Functional Architecture

In our solution, proper acquisition of patient information (including demographic, imaging, disease specific, etc) is accomplished via a web server, which will provide secure access (https) for each user and maintain their unique identifier and password. This system is datacenter driven which is also used to store associated patient images. The web interface has been built utilizing the latest Web 2.0 principles and tools (PHP, AJAX, XML, etc.).

2.1 Data Collection

Data acquisition requirements present a formidable challenge for all organizations. In migrating from the traditional paper-based systems to electronic systems, many hospitals have chosen to store their patient information and records in a non-distinct-field and non-minable format. Though this method allows for easy digitization of legacy reports, it results in many errors when generating reports or trending. Hospitals are now recognizing that the move to this non-minable digital format does not reveal the necessary data for quality reporting and analysis without a considerable concerted effort, thereby forgoing any benefits to the medium entirely. Here information is not easily translated into knowledge. This has negatively impacted on how healthcare providers view electronic data collection and reporting, which affects the quality of data and documentation [9-12].

The storing and categorizing of clinical data related to from multiple sources not only leads to heterogeneous databases, but also results in difficulties in automating analysis on gathered datasets. Currently, many hospital and research databases are constructed from various national, provincial and private databases consisting of datasets with incomplete and incompatible data fields. Combining these data sources leads to the inevitable consequence of mismatched data, such as – various gaps of missing data riddled across various databases, incompatible fields, redundant and duplicate data markers, conflicting fields and multiple standards. These "dirty data" can cause a wide variety of problems which may lead to incorrect data analysis and eventual improper diagnosis.

2.2 Web-based data collection

A PHP/MySQL system was implemented, tested, and refined for its ease of use. A customized implementation gave us the ability to deal with multimodal data types which provided the flexibility and usability needed for an industry class wide reaching data system – given its online nature. Using an online paradigm was not only flexible, via its installer-less nature and universal access, but also in terms of its ability to be reached from anywhere on the globe.

An informatics framework using these technologies was then selected and utilized in order to setup the informational analysis (informatics, extraction and knowledge transfer) on data from pertinent databases. This system will allow for managing heterogeneous datasets by using specific and well defined interconnects (or hooks – the ability to communicate with other hospital systems). The system has a well defined workflow (patient based or unique study ID workflow) and requires the interconnects to be defined in order to automatically populate the fields from the various DBMS.

2.3 Imaging Module

To ensure that a comprehensive view of a patient is available, we incorporate a "holistic" view of intra patient data. We have built an imaging platform where all

associated patient images (whether CT, Ultrasound, MRI, etc) is located and contained within the record and is accessed within the platform (such that an external PACS system need not be separately accessed). Imaging workflow has also been built and tested with various DICOM image format versions along with many common image formats.

This allows the clinician to analyze a complete patient record, including all associated test results in order to verify findings. Simple imaging tools (such as magnify and reorient) allow the clinician to highlight and focus on various aspects of the patient images. Clinicians can also download images to their machine for further analysis using proprietary tools, if desired. This imaging platform is currently being extended to include multimodal datasets, online registration and segmentation algorithms.

Bandwidth and processor limitations require the translation of native image datasets to formats more compatible with a web browser or PDA. This entails the processing of images in order to enhance elements of the image to highlight important areas, *e.g.*, plaque, and to enable the user to manipulate the image. Image datasets are converted from their native DICOM image file format and stored in a TIFF or GIF file when accessed. DICOM tags and Transfer Syntax UID's are translated and stored in raw format accompanying their related images. By focusing on delivery of images and information via a browser, we are able to deliver the same information on tablets which are intended to be used within clinics where review of the images and related information is done by clinical personnel.

Figure 1 demonstrates a template screening the inclusion of imaged data within the platform. Images can be previewed, zoomed-in or uploaded/downloaded by the current user from this view.

2.4 Portable

Interfaces are currently being developed to use the proposed platform on handheld devices (such as a PDA, iPhone/iPad, etc). These interfaces are preferred over a standard browser since it would provide an efficient means for clinicians to traverse different area's of their clinic with the ease of a lightweight device.

The efficient use of the limited viewing area on the handheld will provide rapid access to the platform while considering the limited hardware subsystems (memory, graphics and CPU) of the device. For example, imaging data is compressed on the web server and delivered to a mobile device, since they are limited by wireless transmission (WLAN and 3G/EDGE) when receiving the data, and contain low-power CPU's, when processing heavy data.

3 Prostate Image Study Trial

A multi-centered clinical trial involving over 40 subjects and thousands of prostate images is currently trialing our platform for both subject data collection and image management needs. Images currently housed on the system include (but are not

limited to): MRI (3T and 9T), CT, PET, SPECT, pathology images and 3D TRUS. Our platform has been customized to accomplish the following for this study:

- provide all data subsets within a common platform interface (these templates have been created in-house),
- provide an interface for imaged data (MRI, CT, PET, SPECT, pathology, US) to align with conventionally recorded clinical data, for the purpose of enhanced review and analysis,
- provide an interface for multiple global search terms (universal search),
- provide local data reporting and simplified in browser modeling (simple analytics of various fields, mainly a reporting feature),
- provide data validation ranges for all fields entered within the platform, preventing the miscellaneous data entry error.

The customized functionality for this image based study provided a proper workflow to demonstrate the platforms usability and efficacy. The platform was further built with a system specific customized map in order to deal with the many technical aspects during information merging. Missing and acquired data, the variations in field formats (date, names, etc), incompatible data fields (ID's, primary keys, query sets, etc) and conflicting fields (the use of different standards) were the some of the variations handled across different centre's.

3.1 Outcomes of Study

The system is currently providing services for the various sites involved with the study. The platform was refined such that it will best demonstrate the potential of an integrated mining tool for studies using various heterogeneous datasets and traditional paper/CD mechanisms.

The following characteristics were added to the platform as a request of further functionality for the study:

- Administrative: all permissions related to each field within a table can be granted and revoked from any user on the system (setting of permissions and access control).
- Field look up lists can be maintained from a management portal for administrators.
- Subjects/patients and events can be re-activated/deactivated (never truly delete a record).
- Messages regarding illegitimate entries within the database (based on validation rules) will be presented to the administrator for processing.
- Users can be added to the system and appropriate permissions assigned.
- Logs can be accessed in order to ascertain the times of relevant updates and additions to the system.
- An audit trail of all data accesses and data modifications is available.
- The ability to search and query all datasets housed within the platform, such that researchers will have the ability to manage their own datasets and generate reports relevant to their ongoing research.

- A common communication channel was established for connectivity between the proposed platform and other database systems that will provide the ability to poll data from external sources.
- An interface for coordinating multiple external datasets (e.g. addressing the need for homogeneity) conducting preliminary disease or risk modeling to help inform clinical decision making.

Now that a large subset of patients (over forty) have been collected on the platform, rigorous web-based mathematical analysis is currently being developed and applied to the dataset in order to uncover trends and patterns (over the standard statistical methods). Novel techniques may expose significant results that would lead to eventual improved patient care.

4 Conclusions

In this paper we have presented a patient centric web-based data collection system, facilitating the electronic health record keeping along with the medical record keeping ability. This system provides an interface for imaged data to align with conventionally recorded clinical data, for the purpose of enhanced review and analysis. The capture and analysis of imaging information is vital to patients and for clinicians to make informed decisions about a patient's long term treatment and recovery paths. This platform aims to incorporate imaging analysis information along with a web-based view of current images about the patient (within the patient's record).

We want to illustrate the fact that many EMR systems are currently being retrofitted to a clinician or researcher's requirements and in fact these solutions are more problematic than helpful. A clear idea about workflow and how researchers work and think are imperative if these systems are to provide the usefulness we expect to advance research, support decision making and improved patient safety. To that end a collaborative approach is necessary.

This system was pilot tested and validated on a large multi-centered study which improved core functionality and system efficacy at various levels. System improvements will continue to take place throughout the current trials and others being conducted.

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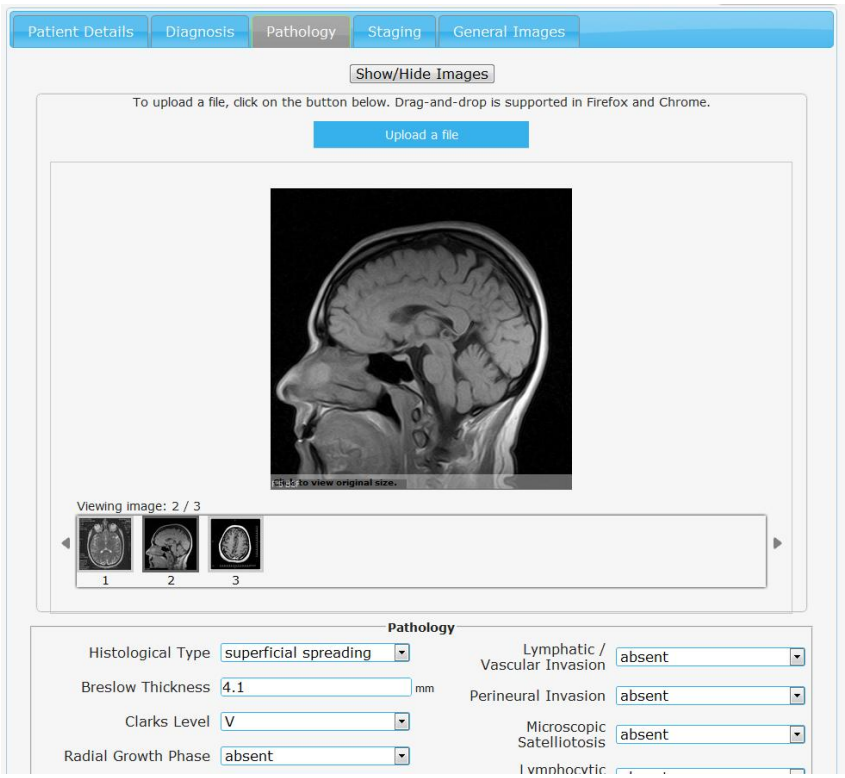

Figure 1. The image viewing module of the presented platform.