Standards for Physiological Data Transmission and Archiving for the Support of the Service of Critical Care

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Abstract—Physiological data is monitored and displayed on medical devices around the world every day, and the volume of this data is steadily increasing and newer monitoring devices enter the clinical setting. However, the vast majority of this data is lost since it is most often displayed once as it is recorded, perhaps replayed one or more times while it exists in the device's volatile memory. What little data that is permanently recorded is most commonly saved through hand written annotations, in paper records and in some limited samples stored on hospital clinical information systems. Meanwhile, current methods of data analysis provide opportunities to utilize this data for improved care of these same critical care patients. A major inhibitor to this becoming reality is the lack of standards for the representation, transmission and storage of physiological data. HL7, for example, does not include definitions for time series data. Research into the use of these data will soon be reaching the clinical setting and the need for such standards to be defined is becoming urgent.

Introduction

Our research is focused on the collection and analysis of clinical physiological data streams both in real time and for later offline analysis [1]. The goal of this research is to use these streams for computer aided diagnostics using evidence based rules. However, the lack of standardized formats for transmission and archiving of these data limits access to these data -- and those collected by others -- and prevents significant amounts of analysis for the identification of such rules from being carried out.

We are developing just such standards and exploring opportunities with Canada Health Infoway (www.infoway-inforoute.ca) and the Canadian Neonatal Network (www.canadianneonatalnetwork.org) to develop such standards through a demonstration project with IBM Research's TJ Watson Research Center, NY and the Hospital for Sick Children in Toronto [2].

Physiological Data Streams: A Case Study

Within Intensive Care Units (ICUs), there are typically found several types of devices that are collecting physiological patient data rates of up one thousand sampled per second per sensor. In the example of monitoring brain electrical activity (electroencephalograms or EEG), this might include as many as 14 streams of EEG at 1 kHz per stream. Simultaneous collection for other devices might produce another 12 channels of heart activity monitoring (electrocardiographs or ECG) and 3 streams of intravenous blood pressure (iBP) monitoring, each also at 1 kHz. Additionally, these and other devices produce raw or derived streams of data (e.g. heart rate [HR] information at 1 Hz) also in real-time. Modern medical devices typically allow for storage of these data for review by physicians, and, while many allow for transfer of these data for backup or inclusion in clinical information systems, it is very unusual to electronically archive more than a limited number of samples, statistics and/or snapshots of these data. On the other hand many studies have shown that there is significant information contained in these data which could be exploited for diagnostic purposes.

In the Artemis project, we are working with IBM's TJ Watson Research Center, NY to develop a system for real-time event processing of precisely these data types, as well as offline storage for analysis and development of novel, evidence-based diagnostic routines. While much of the data that is being produced can readily be stored in standard Health Level 7 (HL7) format, for example as snippets and snapshots, it is unclear how large amounts of continuous data will be stored. As an illustrative example of the challenges, a prematurely born baby might be in an NICU for months, while being continually monitored for nearly the entire time. Current medical data transmission, e.g. HL7 of Digital Imaging and Communications in Medicine (DICOM), do not provide clear methods to transmit or store such continually monitored data, and current clinical information systems do now support storage of these, partially as a result. However, research and clinical experience show that such data can be very informative for immediate diagnostics and for development of new diagnostic methods.

Within our research we have previously proposed two alternatives for the transmission of physiological data. Firstly, utilising the service oriented architecture based web services in [3] and secondly by extending DICOM principles in [6].

Integration with Electronic Medical Records

While the methods to use these types of data for diagnostic purposed are still at the early stages of development, the ability to record and store them is there and the potential benefit of doing so is significant [4, 5]. In the example of prematurely born babies, the ability to help them survive to maturity has improved drastically over the past several decades. However, the long term effects of both the premature birth itself and of the treatments required to help them survive are unclear [6]. For these babies, if more complete medical records of their birth and during their stay at the NICU can be stored, there is enormous potential in using these records for follow-up treatment and studies to better understand how to treat these people as they grow to maturity and to improve treatment of future prematurely born infants.

In order to allow for these data to be made compatible with electronic health record systems and with clinical research repositories, standards need to be selected and/or developed. Many different standards exist and several of them support aspects of continuous physiological data streams. As proposed previously, the DICOM standard can be used for these data if they are treated as 1-dimensional images, instead of the usual use of DICOM which is for 2- or 3-dimensional images. DICOM furthermore supports “mosaics”, which is intended to allow for images which overlap and to allow them to be used to create a more complete image from several limited perspective images. The same idea can be used to store and transmit multiple segments of 1-dimensional data streams, and to construct the larger stream from them [7]. However, it is not clear that this is a good approach to continuous, multi-rate and heterogenous data streams.

Some other notable efforts to enable parts of this are, however, in progress. For example the Rosetta Terminology Mapping (RTM) profile aims to harmonize the use of existing ISO/IEEE 11073-10101 nomenclature terms for systems compliant with the Integrate Health Enterprise (IHE) Patient Care Device (PCD) profiles [8]. The RTM profile would facilitate safe and interoperable communication between devices and systems, an important step forward.

The issues that exist in storing these data streams in EMRs also include questions of data compression [9] and methods of temporal abstraction [10, 11]. On top of these are issues of how these compression and abstraction methods might affect the quality of the data stored and how it can later be used. And so it is important to consider also the transmission of archiving of details on the methods used to accomplish these so that, if necessary, the effect of compression or abstraction on diagnoses can also be evaluated.

In the Artemis project, NICU patient data is being collected and stored and will be used to develop new, evidence-based clinical rules for diagnostics. The data is recorded and analysed in real-time and through archiving of the data will provide a rich repository of data for clinical research. These data will also be made available to patient EMRs as soon as the standards can be determined on how to do so.

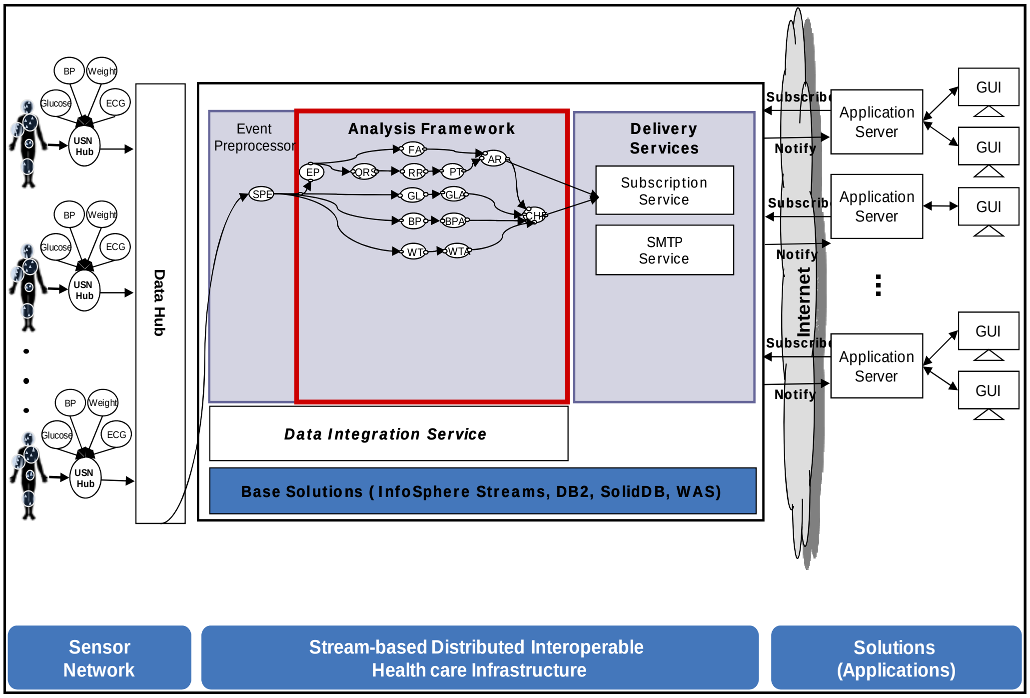

Figure 1: Artemis system for real-time event stream processing and archiving. Courtesy of IBM Research.

Through the Artemis project a demonstration project is proposed with the Canadian Neonatal Network and Canada Health Infoways to show how physiological data streams can be include in EMRs in the Canadian health system. Existing standards will be leveraged and specifications will be developed on how to use those standards to allow for transmission and storage of these records in EMRs.

Conclusions

The potential for the analysis of physiological data streams to support real-time clinical management and historical clinical research is significant. The classical nature of the electronic health record, supporting patient care by many providers in varied locations over their lifetime drives the need for standards to support this new area of medical support. Our research is working to develop standards for integration within the Canadian EHR commencing at birth through Neonatal Intensive Care Units.

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