High Impact Blow Detection over a Reactive Mobile-Cloud Framework

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Abstract—Brain injury is quite common in athletes due to the frequent and high level of impact, especially in football and hockey. One of the most challenging problems faced by medical personnel responsible for the health care of athletes is the recognition and management of concussions [1, 2]. With the advancements in sensor technology, medical imaging, mobile devices, wireless communications, and cloud computing, we have opportunities to monitor and analyze the impact between athletes in real time. The research will assist team doctors to immediately identify head injuries among athletes and drive the development of new technology to be used for protecting the athletes more efficiently. We propose a Reactive Mobile Cloud-based framework that will be utilized to effectively manage both the textual and image data in DICOM format; allowing us to create a repository of information on each player throughout the length of their career.

Keywords - cloud computing, brain injury, athletes, real-time, Mobile Cloud-based framework, medical images, sensor, DICOM.

I. INTRODUCTION

Head injuries in sports are occurring at an epidemic level. The Center for Disease Control (CDC) and Prevention estimates that as many as 300,000 sports-related mild traumatic brain injuries (MTBI), also referred to as concussions, occur in the United States each year, with approximately 1/3 of these occurring in football [3, 4]. The medical practitioners and researchers have adopted new innovative tools and methods to attempt to detect, identify, and treat the injured athletes. This research proposes a highly innovative Mobile Cloud framework that will assist in the clinical evaluation, real-time notification, and additional research tools for the protection and treatment of MTBI.

A. Problem and Challenge

To measure the direction and level of the impact, an accelerate sensor needs to be planted in the helmet of athletes. This sensor requires a small, unobtrusive, and compact design. Due to the size of the sensor, resources regarding the computation ability are limited. To solve this problem, we propose a novel system architecture which stores the impact data collected by the system in the cloud based environment.

Another problem lies in that the distinguishing of different kinds of impact by human being is time-consuming and inaccurate. Machine learning methods such as Adaboost have been successfully applied in texture detection, face detection, face recognizing and medical organ detection [5, 6]. This method will be implemented to allow our team to distinguish the different kinds of impacts collected by the remote sensors.

In regards to balancing the quality of service with network consumption, the challenges will be (1) developing a system which is able to monitor a context (dataset quality, network throughput, user demands) and (2) properly delivering and/or displaying archived images. Since the chosen mobile platform is an Android OS smart phone, various API's exist for monitoring many of these contexts [7]. A non-trivial aspect of this project will be the porting of the existing scan viewing programs to the mobile device. Furthermore, the computation of offloading includes establishing network communication between the cloud based system and the mobile device.

B. Goal and Motivation

Various systems that are designed to evaluate, correlations between head acceleration measurements and concussions are in the early stages of research and development. As the systems continue the ongoing tests for accuracy and response capability, new systems must be developed to support the technology. According to the FDA, the usage of Smartphone's for diagnostic in Radiology is prohibited [8]. The technology that this research proposes will make advancement towards utilizing these new technologies by providing valuable data that will drive the acceptance of its application in sports medicine.

To reiterate the problem, today medical personnel in the sport of football have limited access to vital data regarding the athletes' on the field. (1) Our team proposes an integrated agile and adaptive scan viewing system for a mobile device that will provide a deliver method of both historical and real-time data. (2) Using a Mobile Cloud based solution, the research will allow for the storage and analysis of both the textual and images associated with each athlete. Heavily focused on the integration of Mobile Cloud technologies, the goal is to utilize the resources in the Mobile Cloud to execute computationally intensive operations, such as searching, data mining, and multimedia processing [9].

The variables of study will be a context as input, and network consumption and quality of service as output. Context is described as a set of variables, which express the users requested level of service, and the current network throughput. Quality of service is defined as the image resolution of the scans as well as the response time to changes in this image.

Clinically relevant data in patient care, such as physiological parameters, laboratory results, and radiological imaging are often maintained separately. This segregation limits complete data integration on current existing databases [10].

The goal of this research is to create an agile and adaptive viewing system for a mobile device to assist the team doctor to monitor and treat the athlete on the football field. The motivation of this research is to create a set of systems that are collecting, analyzing, and transmitting the data of the impact. In addition, the systems will allow images to be rendered using the set standards set forth by Digital Imaging and Communications in Medicine (DICOM) via a mobile device. These standards were initially developed to address connectivity and inter-operability problems in radiology, but today there are sections of the DICOM standard which define objects for many other modalities, including ultrasound, X-ray, and radiotherapy [11]. Utilizing set standards such as DICOM, will allow us to develop a solution that can be tested against existing and newly developed systems.

II. Related Work

This section provides a brief background on both mobile cloud computing and information dissemination in a Cloud environment. Cloud computing for mobile devices has a major benefit in that resource-constrained mobile devices can outsource computation, communication, and resource intensive operations to the cloud. There are already mobile applications that implement DICOM network protocol [12, 13] and take full advantage of retrieving DICOM images from every Picture Archiving and Communication System (PACS). DICOM protocol is a complex process [14].

A. *Cloud Computing Techniques*

To start, much of the recent progress in the area begins with utilizing computers in analyzing the impact data per event, per season, and/or the entire career of the athletes. There is an opportunity to actively use applications for creating a compilation of data that can be used to locate previously undetected patterns in the mountains of research data and medical imagery.

Using our cloud computing based framework, will allow us to provide a networked online storage component. This will allow the team to provide web based accessed to both the mobile and networked workstation platforms. This technique will allow the integration of systems in most radiology departments. For instance a system such as PACS can be integrated with the real-time sensor data to create full picture for the practitioner and/or researcher.

The PACS consists of several major components: The imaging modalities, a secured network for the transmission of patient information, workstations for interpreting and reviewing images, and archives for the storage and retrieval of images and reports.

Using a Mobile Cloud based solution will allow the system users to import data in many formats. The additional functionality enables access for mobile users and the remote user that has Internet access. This approach enables access to images, interpretations, and related data, which lessens the isolation of the medical data.

B. *DICOM and Analysis over Time*

DICOM has become a standard diagnosis image format in medicine. Displaying DICOM dataset on mobile device is significant for treatment and potentially could lead to a revolution to the diagnosis. As the real-time requirement, the time spent on sending data through the mobile network is quite crucial to the system.

The challenge of the transmission involves providing high fidelity (in the form of minimal transitional frame drops and image resolution) while providing a tradeoff with high data volume transmission and the athletes' privacy.

However, interpreting these images is complex and time consuming. In DICOM, 12-bit is used for displaying a pixel but 16-bit needs to be used to store the whole information for a pixel. For instance, to store a dataset of a patient's lung, each dataset contains 450 ~ 600 slices of 512-by-512-pixels. The voxel size of these slices ranges from 0.5 to 0.7 mm in the axial plane, and the slice thickness is around 0.5 mm. The storage of the whole dataset is around 500 MB [15].

Also, these archives are universalizing and standardizing formats and descriptions so that they are more searchable for everyone. For the past decade we have been able to get data and now our technology allows us to share findings and research much easier.

In particular, information retrieval from disparate and large data sets in hospitals remains problematic. Often a query of Radiology Information System (RIS) or PACS database is limited by a search for individual patients either by name or identification number [16, 17].

C. *Machine learning method: Adaboost*

AdaBoost, short for Adaptive Boosting [18], is historically the first and perhaps the most popular member of the boosting algorithm family. The basic idea behind AdaBoost is to repeatedly pick a weak learner with respect to a distribution and add them together to form a final strong classifier. A weak learner, intuitively, is a classifier that only slightly correlates with the true classification. A commonly used weak classifier, namely the decision stump, makes a prediction based on the value of a single input feature [6].

The first real-world application of AdaBoost came from Viola's breakthrough work on face detection [5]. Their learning algorithm, based on AdaBoost, selects the most visually relevant features from thousands of Haar features, each corresponding to a single decision stump weak learner. Their final face detector is a cascade of boosted strong classifiers, which is used to scan the images and obtain candidate detections.

D. *System Overview*

The system is divided into four layers: (1) In the first layer, a small acceleration sensor is attached to the helmet of each player. The sensor can detect the direction and strength of the impact blow and then transmit the results to the next layer; (2) Then, a receiver that resides in close proximity to the football field receives and transmits the information to a cloud based computer on the internet; (3) The cloud computer receives, tags, and reorganizes the information by applying machine learning methods Adaboost, which will classify the different data sets into predefined groups; (4) In essence, if a high impact blow is detected, the system will trigger an alarm, which includes the severity of the impact and any available textual and/or imagery for the respective player. The alarm will reach the team doctor's mobile device. The device could be an iPad, a mobile phone or a laptop.

E. System Architecture

First, we introduce a service-oriented communication architecture approach that will allow the researchers and team doctors to query complete head impact data for an athlete's entire career. This architecture will allow services to communicate with each other; allowing for data passing, image rendering, and/or image and data compilation.

Second, to reduce the security uncertainties, we implement a novel attribute-based trust management mechanism including security services such as identity management, policy management and enforcement, and attribute-based key management [19]. Through a service-layered Cloud infrastructure, the trust management mechanism can address the inter-operability issues effectively, and thus reduce the security setup uncertainty.

Third, we will tag the data received from each sensor with a unique identifier to reduce the mobility uncertainty, we incorporate each player's record as a virtualized component of the Cloud. These actions will allow us to address communication and computation deficiencies of sensor data and brain images.

The collection of medical data can potentially benefit from the information processing and collection, such as information search, data processing, data mining, network status monitoring, and field sensing shown below in figure 1.

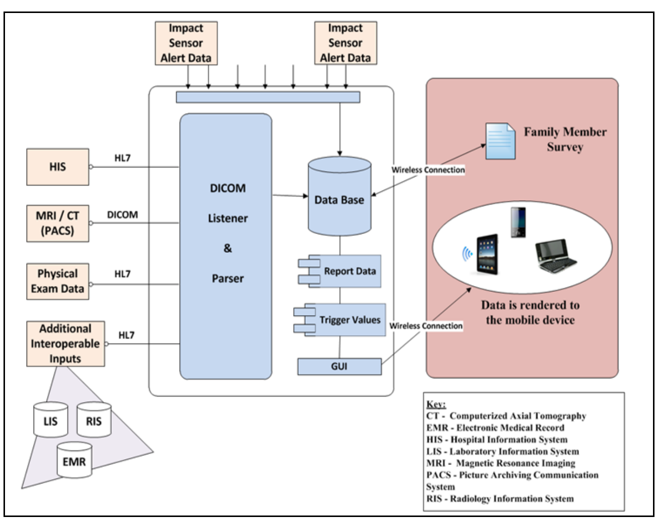

Figure 1. System Architecture

Only when these three aspects are combined can a system truly be desirable to the widest area of users. Such a system will offer most efficiently use its own resources while maintaining the requirements of the individual user.

- Techniques for increasing transparency while maintaining appropriate levels of security: Tagging, e.g., data type tagging and policy tagging
- Privacy preserving data provenance systems, e.g., tracing data end-to-end through systems;

The wireless sensor will communicate using the ISM (Industrial, Scientific and Medical) radio bands and HL7 compliant protocols, which integrates with all industry-standard external records systems. The aim of our framework is to develop a health informatics system that will store and query information with different formats (e.g., text, XML, imaging) following different standards (e.g., HL7, DICOM) from different medical systems (e.g., EMR, RIS).

The system will be deployed to collect head injury data and allow researchers to make better predictions for future head injuries. The platform will provide key medical and rehabilitation personnel with timely information regarding the athlete's. The key medical personnel include the following:

- First Responders who are the initial emergency medical personnel that respond in the event of a high impact events
- Physical Therapists who help patients regain their coordination, flexibility, and range of motion, and to address pain and stiffness
- Occupational Therapists who help patients relearn how to perform the simple activities of daily living
- Neuropsychologists, whose testing of patients' functional abilities helps the health care team identify specific areas of cognitive functioning that require specific rehabilitative efforts, and then measure progress toward addressing deficits
- Psychiatrists, who help patients to better, manage their cognitive, emotional and behavioral symptoms

In addition, the Reactive Mobile-Cloud Framework provides a mobile application that is designed to communicate with the athlete and family members during their recovery. Existing recovery procedures provide surveys for the athletes' family members, which in the past where distributed through the mail, administered in person, and/or over the telephone.

F. Experiment Requirement

In a football game, different positions receive various kinds and severity level of impact. For instance, linemen receive continually, but low-level frontal blows. While the impacts sustained by wide receivers are less per game, they have a higher probability of severe impact. The direction of receivers' impact is difficult to predict, which increase the risk of injury and hard for diagnosis without advanced equipment.

In order to collect and measure the impact data, we will execute the following steps for experiment:

- Calibration of the selected impact sensors
- Data Collection - Data is accumulated, stored, and analyzed in the system using machine learning methods, which provide feedback and guidance for multiple events rather than a single event.

- Alert Mechanisms - The system will be testing for performance in conjunction with stress testing.

III. Discussion

The proposed technical approaches are in two main areas: First, integration of our Mobile Cloud based solution involves in the issues such as service provisioning, resource allocation, and security. The following areas need to be noticed throughout the future research:

- Stepwise manner
- Accurate tagging of data and images
- Security isolation, and the integration of processing and operations of Cloud
- Fault tolerance in such a distributed system

By applying our Mobile Cloud based solution, the system can do computationally intensive operations, such as searching, data mining, and multimedia processing. Second, the Mobile Cloud needs to be adaptive to the environment. For the sake of power, the sensor switches between the off and on mode automatically. Furthermore, based on the quality requirement, our system will send different resolution images by detecting the type of mobile device.

IV. Conclusion

In this paper, a severe event about the athletes' brain injury is mentioned. In order to find the solution to protect the athletes, we propose an innovative system for collection, delivery, and analysis of textual and medical imagery data. This system, combining technologies of sensor, wireless mobile communication, cloud computation, machine learning and image processing, could aid researchers and doctors to realize the severity level of the impact between athletes in real time. Furthermore, it can collect and store the data for the lifetime treatment of the athletes.

One of the potential applications of this system is to provide the baseline to modify the rules in NFL. Also, the system can be used to measure the efficiency of protective facilities.

In the future, we will continue to investigate various models and algorithms that can help the system achieve system-level functionalities such as identity management, key management, policy enforcement, and context-awareness routing and risk assessment.

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