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CHOIS: Enabling grid technologies for obesity surveillance and control

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Abstract. CHOIS, the Child Health and Obesity Informatics System [2], is developed using open source portal technology with three-tiered Open Grid Services Architecture, an accepted standard for accessing Grid Computing and other services under Open Grid Collaborating Environments (OGCE). Its web application provides web based forms with 112 different fields to enter data ranging from demographic, height & weight for BMI, to genomic information. Automatic computation of BMI, BMI percentile and the risk of obesity alert are embedded into this system. After successful testing of the prototype, CHOIS is now ready to be used by the Illinois Department of Human Services School Health program (DHS) for obesity surveillance. This HIPAA & FERPA compliant secure system, integrating large databases in a high performance grid computing environment, enables school-nurse to collect data on school children and report statistical and surveillance information on BMI to identify those at-risk and obese for obesity prevention and intervention programs.

Keywords. Obesity, Body Mass Index (BMI), Portal technology, OGCE, wellness program, grid technology, mobile technology

Introduction

Obesity is from the Latin word *obesitas*, which means "stout, fat, or plump". In simple term, it can be defined as the excessive accumulation of fat in certain parts of the body to the extent that it may have an adverse affect on health, leading to reduced life expectancy. This metabolic disorder is often associated with an increased risk for developing a variety of serious health related conditions including social and emotional problems [1, 2]. Recent study has shown that the maternal obesity may even cause a serious congenital heart defect to the new-born baby [3]. The imbalance of energy intake and energy expenditure in the body is the underlying cause of obesity [4 and the references therein]. A 2006 review identified ten possible contributors to the recent increase of obesity [6]. It is the result of interplay between genetic and environmental

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factors. Polymorphisms in various genes controlling appetite and metabolism predispose to obesity when sufficient calories are present. As of 2006, more than 41 of these gene-sites have been linked to the development of obesity when a favorable environment is present [7]. A sedentary lifestyle obviously plays a significant role in obesity [8]. At an individual level, a combination of excessive caloric intake, lack of physical activity, and genetic susceptibility is thought to explain most cases of obesity. At a societal level, increasing rates of obesity are apparently due to an easily accessible and palatable diet, increased reliance on automobiles and automation [9]. Such behavior that contributes to increased risk for obesity is affected by multiple individual-level factors and socio-environmental factors [10, 11]. These factors, heterogeneous in nature and interdependent to each other, interact dynamically [12, 13]. Obesity is now one of the most prevalent chronic diseases globally, especially in the United States. Since last two decades, it has become so common that in 1997 the World Health Organization (WHO) formally recognized it as a global epidemic [14]. Obesity rates in the United States increased from 14.5% to 30.9% in the period of 1971–2000 [15]. The latest U.S. National Health and Nutrition Examination Survey[3] documents that about one third of adults in the United States are now overweight/at-risk and another one third are obese. Recent survey also suggests almost 1/3 of children and adolescents are overweight or obese and 11.3% of children and adolescents are very obese [16]. The widespread availability of nutritional guidelines at USDA[4] and CDC[5] has done little to address the problems of overeating and poor dietary choices [17]. The economic impact of this condition is staggering: in 2008, it has been estimated that more than 147 billion dollars were spent just in the United States for medical costs related to obesity and this estimation does not include the time lost from work [18]. If this trend continues, it has been projected that nearly one-fifth of the healthcare budget in US alone may have to be used for obesity control [13, 19]. Due to all these, obesity has become a major concern in US. President Obama has recently established a task force on childhood obesity to address this issue (White house, Office of the Press Secretary, February 09, 2010).

Development of effective surveillance, prevention, treatment and management strategies to address the health, social and emotional problems associated with overweight, particularly among school-aged children is very critical. Legislation has been passed in several states including in Illinois to screen obese and at-risk children and involve them in wellness program with proper diet and regular physical activity. The American Academy of Pediatrics recommends that Body-Mass-Index (BMI) should be measured on all children as part of normal health supervision. BMI, which is easy to measure and correlates with body fat, assesses the weight status of an individual to identify those at risk and obese. BMI, which is calculated by dividing an individual's weight by the square of his or her height in Standard or Metric measures, is used to define[6] a person as overweight (at-risk) when their BMI is between 25 to 29.9 and obese when it is 30 or greater. It can be further evaluated in terms of fat distribution via the waist–hip ratio and total cardiovascular risk factors [20, 21]. Although the BMI number is calculated the same way for children and adults, the criteria used to interpret the meaning of the BMI number for children and teens are different from those used for

[3] ftp://ftp.cdc.gov/pub/Publications/mmwr/rr/rr4509.pdf
[4] http://www.cnpp.usda.gov/dietaryguidelines.htm
[5] http://www.cdc.gov/nchs/nhanes.htm
[6] http://www.cdc.gov/obesity/defining.html

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adults. For children and teens, BMI age- and sex-specific percentiles are used for two reasons: The amount of body fat changes with age. The amount of body fat differs between girls and boys. The BMI-for-age growth charts[7] of CDC take into account these differences and allow translation of a BMI number into a percentile for a child's sex and age. Many states including the State of Illinois have made it mandatory BMI surveillance program for all students attending the public school system for prevention and intervention. Yet, no method or system was available to implement this program by the DHS. CHOIS has been developed in response to this need, and after successful testing of the prototype, is now ready to be used in the School Health Clinics (SHCs) funded by DHS.

Design and Methods

CHOIS is designed based on OGSA

This system has been developed using Open Source Portal Technology with three-tiered Open Grid Services Architecture (OGSA; Figure 1), an accepted standard [22] for accessing Grid and other services under Open Grid Collaborating Environments (OGCE). OGSA, based on several Web service technologies, is a distributed interaction and computing architecture based around services, assuring interoperability on heterogeneous systems so that different types of resources can

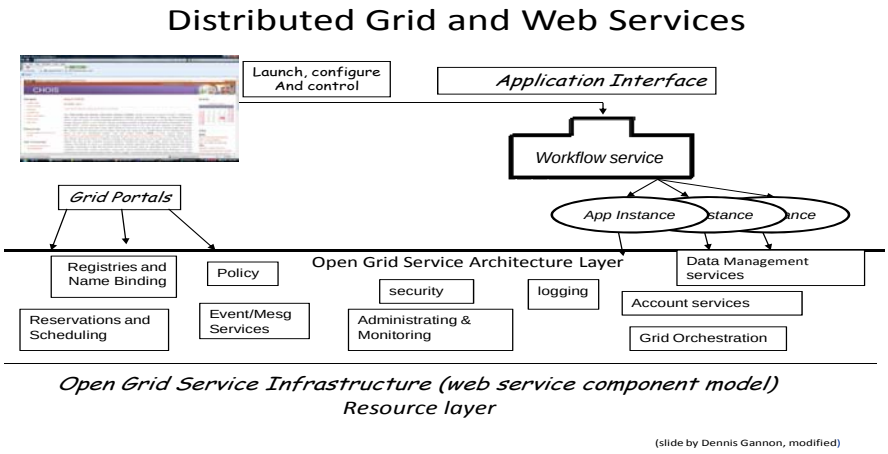

Figure 1. Distributed grid and various web services. This three-tier architecture, an accepted standard for a portal, provides a unified interface for Grid and other services8. It also supports aggregation of services at the back-end.

communicate and share information [23]. OGCE Software system[9] has a bundled set of JSR 168/286 compatible portlets and services for building Grid Portals and related

[7] http://www.cdc.gov/GROWTHcharts/
[8] www.ogce.org
[9] www.collab-ogce.org/ogce

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tools for Web access to Grid and Cloud computing resources. A number of Science Gateways supported by TeraGrid[10] have been built following this approach. As a Campus Champion for Teragrid usage [24], this author (AKD) followed the similar approach for building CHOIS with TeraGrid resources at the back-end. Currently, TeraGrid resources include more than a petaflop of computing capability and more than 30 petabytes of online and archival data storage. Moreover, researchers can access more than 100 discipline-specific databases. Through a set of Web Application Programming Interface (API) of CHOIS built on authenticated services, users will be able to access such resources remotely from anywhere anytime. In addition, effort is underway to provide sustained petaflop computing power of Blue Waters[11] to the researchers when it will become available in 2011. Blue Waters is under development through a joint effort of the UIUC, NCSA, IBM, and the Great Lakes Consortium for Petascale Computation. It is supported by the National Science Foundation and the University of Illinois.

Component-level/modular design approach has been used for designing and developing this Grid portal. One of the components is web application built on PHP/MySQL system, an open source technology, and integrated into this portal. The School Health Service Program run by the DHS for the Illinois public schools requires collection of demographics (age, sex, race, and ethnicity), height and weight, diagnosis codes, procedure codes, insurance status, and documentation of

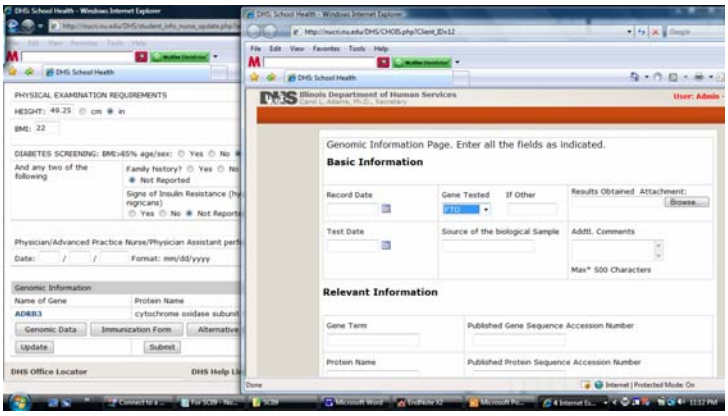

Figure 2. 'Intake form' for recording the genomic information of a patient. Sequence and other data from genomic analysis can be uploaded through this interface. Multiple files can be loaded. This interface also provides a link to the NCBI site for BLAST search, PubMed, etc.

assessed risk behaviors of each student. Various web based forms with 112 fields have been created to capture such data and more on an individual's health conditions. In response to a recent initiative by the National Institute of Health[12], we also included forms to include genomic information from laboratory test results (Figure 2). A set of Web APIs has been developed for remotely uploading laboratory test results including sequence data, microarray analysis results, etc. Once the uploading is successfully

[10] www.teragrid.org
[11] Description at http://www.ncsa.illinois.edu/BlueWaters
[12] NIH RFA-OD-09-003, Challenge Area 15-LM-101

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completed, the server sends a message to the sender through the API acknowledging this event. CHOIS's interface allows the uploading of these data from any remote place and the clinicians at the SHC or School nurses will be able to view those data with appropriate authentication from anywhere through the web. Its interface to access Teragrid supported bioinformatics tools allows a clinician/researcher for comparative genomics/proteomics analysis. Automatic computation of BMI, BMI percentile and the risk of obesity alert are also embedded into CHOIS. Before CHOIS was deployed, BMI was calculated by the school/clinic nurses manually. It has now been realized that the integrity of the BMI measurement is much greater for this automatic computation by CHOIS than that computed by the school/clinic nurses. The electronically computed BMI had an accuracy rate of 99.2 percent compared to a rate of 88.75 percent calculated manually.

Results and Discussion

Some interesting findings have been obtained from the test results of CHOIS. Besides more accuracy of BMI, the system has reduced workload for the healthcare service providers while increasing the quality of services. DHS provides healthcare services through total 39 SHCs. In 2008 alone, these clinics enrolled nearly 80,000 students for medical, dental and mental health visits. For the obesity surveillance project and generating reports on the healthcare services provided by these clinics, DHS had to collect data as email attachments. Each of the 39 SHCs created a zipped file of the deidentified patient data using Clinical Fusion™ and forwarded to the DHS as email attachments. At the state level, those files are unzipped and, through a time consuming process of manually cutting and pasting, entered into an MS Access database. This manual process was slow, repetitive and prone to error. Moreover, the previous system could only collect and evaluate the current year's data and did not allow for evaluation or comparison of data over multiple years. CHOIS replaced such patch quilt system. Now, through its built-in API (Figure 3), each of these 39 SHCs can directly upload the files into CHOIS, thus, eliminating the earlier error prone process. The sender gets a message once the uploading is successfully completed. Once the data are uploaded in the system, a simple scripting at the server side allows the data to be transferred to the already configured MySQL database of CHOIS. In addition, the server side programming also handles the data validation. Earlier, none of the SHCs could view the data submitted to DHS, neither could they see the reports generated on their data or aggregated data based on individual clinic needs. This was because all those data were stored in an MS Access database, thus severely restricting the value of the data. Although a web interface may be created to provide the access to this database, MS Access does not have useful features that a RDBMS[13], such as, MySQL database system can provide. Moreover, with proper normalization, a relational database can remove any data redundancy, which is vital for generating any useful report. Now the clinics will have both the capability of accessing standardized reports and the ability to request unique data queries based on individual clinic needs. The database for CHOIS is located at NCSA for providing uninterrupted web access. In addition, this server is supported by high-performance computing, thus, enabling faster analysis for generating reports.

[13] Relational Database Management System

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The access to the data and the report is secured at multiple levels following HIPAA and FERPA regulations in addition to the usual protections imposed on medical data. Unique identity of an individual patient, such as, name, data of birth, address, etc. is hidden before submission of patient data into CHOIS. Users are required to enter into the system after authentication (login/encrypted password) and can view the data/report following a role-based accessibility. A user can be given full access, read-only access, or no access to various modules and/or functions within the database according to his/her responsibility/role. Each user is provided a unique login and password. In addition to these, each session is time stamped and records the authenticated user. A session normally is set to end after 30 minutes if the system is not used by the user. In addition, a server certificate is in place for accessing securely.

Figure 3. Web interface for uploading files into CHOIS. The csv/excel file generated from the database of Clinical Fusion™ can be uploaded directly into the system through this interface eliminating prior error prone process.

This portal also serves as a gateway to multiple data analysis tools available from open source. We are also integrating after customization a variety of relevant software tools that are available at NCSA and elsewhere. Work is in progress for development of web based tools including SMS-based alert system, a data integration tool, a *Decision Support System* (DSS), to name a few. This agent based system will guide an individual for proper diet and physical activity depending on his/her health profile generated by the system. Its various analytical tools will allow the physician/specialist for analysis of various data types and data formats. As an example, NCSA's Medical Image Analytics will allow a Radiologist to analyze X-ray data. Modern technologies including XML based web services have been used while developing such tools. Recently, we have also developed mCHOIS[14], a mobile version for using at the point-of-care through smart phones. For development of the application, we have used Android-based smart phone, a Google phone, which comes with valuable features including Geospatial Information System (GIS) for location based services. Android is an Open Source Operating system enabling the software developers to develop applications where access to the source code is needed. mCHOIS, can be used to input the necessary data on an individual and the data can be stored in the SQLite

[14] Manuscript is in preparation

database of the phone. Before sending this data, it is converted into an XML formate. With the access of the internet, either through the 3G broadband or through wifi built-in in the Google phone, this XML file can be sent to the database of CHOIS remotely. This mobile version also allows a user to update a file and visualize the data through the browser. This application has been successfully field tested and is now ready to be deployed.

Considering that in 2008 alone, nearly 80,000 patients were registered into SHCs, it is anticipated that this system will eventually need space for storing terabyte or more amount of data ranging from text, graphics, audio, and video. This portal is supported by a data grid of NUCRI[15] [25] to store massive amount of health related data for further analysis. This data grid is located at the San Diego Supercomputing Center (SDSC) and is a part of the WUN data grid network and archival system. Remote management of this data grid infrastructure using ezSRB was developed earlier [26] for managing data through Storage Resource Broker (SRB). Effort is now underway to modify this web service for managing data through iROD[16].

CHOIS: Gateway for education, training and research materials

Approximately 35,000 health education encounters were provided through small group or classroom activities at SHCs in 2008 alone. CHOIS is designed to provide such educational information and training materials through web. *Drupal*, another open source software system that utilizes MySQL database with PHP scripting language, has been chosen as a Content Management System (CMS) for CHOIS. Among the CMSs available in the Open Source, we chose Drupal[17] because it has a dedicated large group of developers that provides support services. Moreover, a significant number of web sites (e.g., NASA, HASTAC.org, artcaonline.org; also see: Drupal's web site[8]) have been developed based on Drupal. Because the source code of Drupal is freely available under the terms of the GNU/General Public License, customization of this CMS is possible. Drupal provides a rich set of multiple functionalities through modules. Among the modules, we used 'Blog' that can be customized to set up a personal blog or a group blog. This blog can be used to post personal thoughts, share information among the group, discuss on a specific topic or event related to healthcare. A robust personalization environment is at the core of Drupal. Both the content and the presentation environment can be individualized based on user-defined preferences. 'Wiki' helps in setting up a network of collaborators for writing a document as co-authors or co-edit. Drupal's 'Forum' module provides the functionality of participating in a threaded discussion. Its 'Message' module provides the functionality of sending private and internal messages to other registered users of CHOIS. Drupal has role based permission system. Its administrators don't have to setup permissions for each user. Instead, they assign permissions to roles and then group like users into a role group. This allows anyone to update the information in its web site with admin privilege. Its text editor functionality is very helpful for the users who does not know html. Another advantage of using Drupal is its RDF/RSS function.

[15] http://nucri.nu.edu

[16] https://www.irods.org/pubs/DICE_iRODS_White_Paper-08.pdf

[17] www.drupal.org

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Once the user selects some obesity related web sites, such as, that of NICHD[18], CDC[19], WHO[20], NIDDK[21], and related, such as, Genome Wide Association Studies[22], Biomedical Information Science and Technology Initiative[23], Online Mendelian Inheritance in Man[24], etc., it will feed the information automatically. Presently, CHOIS provides RSS feed from NCBI[25], CDC, and WHO. Drupal can export the web contents in RDF/RSS format for others to gather that information. This is a very powerful feature for aggregating information. Through this CMS of CHOIS, we update the Obesity related information periodically for the viewers to obtain relevant information[26]. It also links some useful web sites for research: the National Human Genome Research Institute (NHGRI)'s web site is among those. This site provides a search tool for obtaining genomic information on diseases. Our attempt to search 'Obesity' in this database[27] yielded a set of genes with source of information (publication), replication sample size, chromosomal location, strongest SNP-risk allele, risk allele frequency, among others. Such information will be useful while creating agent based model [13] for clinical decision-making. Similarly, software tools and databases available at NCBI[28] and through Biology Workbench[29] can also be accessed through CHOIS for education and research. These and other such databases can be used for data integration using *MedCurator*[30] of CHOIS. It may be noted that Drupal's in-built search module is robust for quick searching any contents in its database.

In addition, we are developing a 3D-virtual space for education and learning more about obesity through social networking. It is known that participation in wellness program with proper diet and physical activity are necessary to control obese condition [11-13]. However, participation in a free dialogue by at-risk and obese children would obviously help controlling obesity by making intelligent decision regarding the life style. Nevertheless, conversation on personal health condition by obese patients is often limited because of emotional problems associated with such health condition. Anonymous participation in a virtual game-like learning environment by these children may encourage free dialogue that may help in coping with the condition and learning more about obesity from the experience of others through social network[31]. Earlier, we used Second Life[32],[33] which provides a free 3D virtual world where users can socialize, connect and create using voice and text chat. The use of Second Life, however, has encountered couple of challenges, ranging from technical and moral to legal. Linden

[18] http://www.nichd.nih.gov/
[19] http://www.cdc.gov/LEANWorks/
[20] http://www.who.int/topics/obesity/
[21] http://win.niddk.nih.gov/statistics/
[22] http://grants.nih.gov/grants/gwas/
[23] http://www.bisti.nih.gov/
[24] http://www.ncbi.nlm.nih.gov/sites/entrez?db=omim
[25] http://www.ncbi.nlm.nih.gov/Entrez/
[26] Viewable at http://nucri.nu.edu/DHS/drupal
[27] http://www.genome.gov/page.cfm?pageID=26525384
[28] http://www.ncbi.nlm.nih.gov/guide/data-software/
[29] http://workbench.sdsc.edu/
[30] Work is in progress
[31] CHOIS interface also provides access to social networking tools; see: http://en.wikipedia.org/wiki/List_of_social_networking_websites
[32] www.secondlife.com
[33] Our earlier work in Second Life for providing learning space can be viewed at http://www.youtube.com/watch?v=6HzesI6grRg

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Lab[34], the provider of the service, has a very limited control, if any, over the quality, safety, morality, legality, truthfulness, or accuracy of various aspects of the service. We are developing *CyberEdWorld* for CHOIS based on Open Cobalt[35], a free and open source virtual world browser and construction toolkit application for accessing, creating, publishing, and hyper linking avatar-based multi-user virtual worlds that are accessible both on local area networks or across the Internet. For this on-going project, children, particularly obese and at-risk students already identified by CHOIS will be provided access to anonymously participate in this learning environment.

The health reform bill that has been signed into law by Obama on March 23rd 2010 requires using Electronic Health Record (EHR) for clinical management of all patients by 2014. An ideal EHR should be able to integrate a variety of data types and data formats, common to medical field, ranging from text (e.g., demographic data), graphics (e.g., X-Ray) to video (e.g., Colonoscopy), for generating reports crossing the "translational barriers" [32] and visualization through its web interface. Moreover, an EHR need to be able to interchange data from other existing EHRs, which would be possible if developed based on standards. However, data standardization and data interchange remains a challenge that needs to be addressed [27-31]. As an example, the DHS provides healthcare services to Illinois students through 39 SHCs. At present, the SHCs and its partnering organizations are using EHRs from multiple vendors. Incidentally, the information from one EHR can not be exchanged to another EHR, causing multiple entries of the same data to various EHRs for various purposes, such as, clinical management, reporting to the DHS, insurance claims, etc. Lack of interoperability between these EHRs is severely limiting the usefulness of any of these EHRs. A national information exchange policy should be in place to adopt accepted standards and make interoperability possible. In addition, medical devices manufactured based on these standards should be able to send the data directly to an EHR. Recently, the Institute of Electrical and Electronics Engineers (IEEE) has published a set of standards, which will be implemented within the context of the International Organization for Standardization (ISO)/IEEE 11073 family of standards addressing the interoperability of medical devices [33]. There are almost 30 large vendors for EHR operating in US [34] to serve this trillion dollar healthcare industry. However, to this author's (AKD) knowledge, none of the EHRs meet all the criteria that the customers are now demanding. There are various reasons. Most importantly, the standards are still evolving [28-30, 35]. We are developing CHOIS based on these standards following the standardized nomenclatures [36] for building a semantic interoperability platform that serves to exchange information. Several communication standards were reviewed and HL7v3 has been selected to exchange health records in our solution. Development of a HL7 broker as a gateway between CHOIS and the HL7 message-based infrastructure is in progress. In future, it will also be possible to send the data from a medical device directly to this system.

In addition, this system is designed to provide tools for both synchronous and asynchronous communications for effective collaboration. AccessGrid of NCSA and

[34] www.lindenlab.com

[35] http://www.duke.edu/~julian/Cobalt/Home.html

InSORS (now IOCOM) are available to us for video conference. These will be seamlessly embedded into this system for the clinicians, researchers and other users to communicate in a real-time.

Conclusion

Automatic computation of BMI, BMI percentile and the risk of obesity alert embedded into CHOIS have made this system very useful for the school-nurse and healthcare service providers in Illinois to collect data on children and report statistical and surveillance information on BMI with more than 99% accuracy to identify those at risk and obese students. Its web API has made it possible for SHCs uploading the data from Clinical Fusion™ directly into the system and, thus reduced the workload and data redundancy. Moreover, this system can be used for surveillance of other chronic diseases including Asthma.

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