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A Comprehensive Health Electronic Record System with MySQL RDMS, QGIS Database and Mongo DB

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Abstract: The advancement in data storage systems and novel data types has made organizations to stop relying on the use of simple client/server I.T infrastructure and leverage more on multiple categories of database systems to keep heterogeneous data. The study exploits the benefits around deploying hybrid relational database management systems and NoSQL systems while developing better electronic health records (EHR) systems within health facilities alongside facility decision support system (FDSS). More particularly, GIS, MySQL and Mongo DB databases were integrated to enhance EHR systems alongside offering improve clinical decision support. The study adopted experimental design to develop the Electronic Health Records System using GIS, MySQL and Mongo DB software to create the database. Findings revealed that the atomicity, consistency, isolation and durability feature typical of relational database management systems guaranteed data security, integrity, ease of access and efficient transaction processing. Mongo database offered the system a more precise internal data structure and solid scalability along with simplified mapping of application objects to the underlying database design. The GIS database enabled a clear visualization of patients' geographical locations, medical facilities, and the physical location of the physicians. Integrating these database systems within the health care arena was instrumental in compelling application systems to adhere to the HIPAA EHR standards without compromising performance and scalability.

Key words: Electronic Health Records, Boresha Integrated EHR database system

I. Introduction

With the new developments around data storage systems and newer data types on the rise, most organizational contexts no longer rely on using simple client/server I.T infrastructure but leveraging more than a single category of database systems to keep heterogeneous data (Baumann, Baker and Elshaug, 2018). Electronic health records (EHR) are patient-specific digital versions of the hard copy forms and charts intended to make patient information readily available whilst guarantying security only to authorized users (Graber, Byrne and Johnston, 2017). EHRs constitute patient-level demographic information, vital signs, progress notes, radiology images, lab test results and billing information among others(Howe, Adams, Hettinger, and Ratwani, 2018). Key functionalities in the EHRs include aiding patients in creating and managing their information and sharing the health-related information with other health care providers and contexts such as medical imaging facilities, pharmacies, workplace clinics and schools. Data associated with the modern service patterns in facilities has commanded a need to effectively gather process and analyze the massive amount of data therein to improve health care and consume data more effectively. Data residing in EHRs constitute different information that could be useful in discovering new medical knowledge. To guarantee a high-quality data analysis and effective data mining, datasets in individual EHRs systems need integration to a general system. The overall EHR platform should take into account prime issues such as scalability, maintainability and performance for an effective operation. Also, the system needs to adhere to the HIPAA standards given the goal to share patient-level information, on the aspect of the security and privacy rules and provisions meant to safeguard medical information.

The database design and development world is strongly getting inclined to NoSQL databases given the benefits such as intrinsic object oriented feature, simplicity and the native properly designed APIs (application programming interfaces) that common place programming languages are able to access (Nøhr *et al.*, 2018). A NoSQL database would provide a solid foundation for storing big data and have a native support for scalability that makes them ideal for usage in a distributed storage. In addition, they scale better for managing multi-media information like x-ray information thus making them ideal for a health-service system.

In this project, we exploit the benefits around deploying hybrid relational database management systems and NoSQL systems while developing better electronic health records (EHR) systems within health facilities alongside facility decision support system (FDSS) (Ratwani *et al.*, 2018). More particularly, GIS, MySQL and Mongo DB databases shall be integrated to enhance EHR systems alongside offering improve clinical decision support. The use of a hybrid data storage system is essential for patients to conveniently locate the nearest health-care providers or hospitals based on their preferred search criteria. These requirements and demands are the basis for the proposal of the Boresha Integrated EHR database system (BIEDS). The hybrid database system shall complement and not replace EHR system that are already in operation, with the overall goal of providing additional functionalities to varied parties in the health care sphere.

II. Literature Review

The advancement in data storage systems and novel data types has made organizations to stop relying on the use of simple client/server I.T infrastructure and leverage more on multiple categories of database systems to keep heterogeneous data (Baumann, Baker and Elshaug, 2018). HIPAA widely described as the Health Insurance Portability and Accountability Act of 1996 affiliated to the United States federal statute signed into law on 21 August 1996 by President Bill Clinton formally defined electronic health records (EHR) as patient-specific digital versions of the hard copy forms and charts intended to make patient information readily available whilst guarantying security only to authorized users (Graber, Byrne and Johnston, 2017). Key functionalities in the EHRs include aiding patients in creating and managing their information and sharing the health-related information with other health care providers and contexts such as medical imaging facilities, pharmacies, workplace clinics and schools. The features aid every healthcare with access to patient health data to participate in offering efficient patient care.

Data associated with the modern service patterns in facilities has commanded a need to effectively gather process and analyze the massive amount of data therein to improve health care and consume data more effectively (Nøhr *et al.*, 2018). Data residing in EHRs constitute different information that could be useful in discovering new medical knowledge. To guarantee a high-quality data analysis and effective data mining, datasets in individual EHRs systems need integration to a general system. The overall EHR platform should consider prime issues such as scalability, maintainability and performance for an effective operation. Also, the system needs to adhere to the HIPAA standards given the goal to share patient-level information, on the aspect of the security and privacy rules and provisions meant to safeguard medical information (Ratwani *et al.,* 2018).

There are numerous database design and implementation options such as entity-attribute value (EAV), object oriented, document based and relational database management systems given the need to attain the ACID property with an overall goal of attaining data availability and consistency (Tutty, Carlasare, Lloyd, and Sinsky, 2019). The database design and development world is strongly getting inclined to NoSQL databases given the benefits such as intrinsic object oriented feature, simplicity and the native properly designed APIs (application programming interfaces) that common place programming languages are able to access (Tutty*et al.*, 2019). A NoSQL database provide a solid foundation for storing big data and support scalability that makes them ideal for usage in a distributed storage. In addition, they scale better for managing multi-media information like x-ray information thus making them ideal for a health-service system. The atomicity, consistency, isolation and durability features typical of relational database management systems guarantee data security, integrity, ease of access and efficient transaction processing (Baumann, Baker and Elshaug, 2018). Mongo database offers the system a more precise internal data structure, fine-tuning, solid scalability along with simplified mapping of application objects to the underlying database design (Howe *et al.,* 2018). The GIS database allows a clear visualization of patients' geographical locations, medical facilities, and the physical location of the physicians (Tutty *et al.*, 2019). Integrating these database systems within the health care arena is instrumental in compelling application systems to adhere to the HIPAA EHR standards without compromising performance and scalability (Ratwani *et al.*, 2018).

With the two solutions –RDBS and NoSQL- offering unique strengths and weaknesses with respect to EHR system database design, none of the options can fulfill a health service need of handling large-scale medical information in isolation. These requirements and demands are the basis for the proposal of the Boresha Integrated EHR database system (BIEDS). The hybrid database system shall complement EHR system that are already in operation, with the overall goal of providing additional functionalities to varied parties in the health care sphere.

III. Methodology

The study adopted experimental design to develop an Electronic Health Record system dubbed Boresha Integrated HER Database system using GIS, MySQL and Mongo DB software. The database design and development strongly inclined towards NoSQL databases given the benefits of intrinsic object orientation, simplicity, and the native properly designed APIs (application programming interfaces) that common place programming languages can access. EHR Data stored at BIEDS was unstructured, structured, and semi-structured.

Structured data was modeled into relational tables using MySQL relational database management system. Specific tables in the model included: Patient table constituting patient name, date of birth, gender, race, physical address and geographical location; Medical practitioner's table constituting training and education, methods of contacts, associated medical facilities and board certifications among others; Facility table constituting name, geographical location, unique number, number of employees, number of BIEDS and any other affiliated medical groups; Clinical appointments table including visit dates, anticipated duration of

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appointment and status of the patient visit and; Billing table constituting patients' account balances, payments, credit card and insurance information.

Unstructured data captured diagnosis information, doctor's prescription notes alongside additional visit related informationin plain text formats. Additional unstructured data within the BIEDS included voice recordings during diagnosis, medical images and any other unstructured information. Semi-structured data captured both structured and unstructured data including Medical history, Allergies, Laboratory results and GIS information. The hybrid BIEDS database system address the shortcomings of the different EHR data set learning to a properly organized storage offering an efficient access alongside promising an improved system performance.

A NoSQL database provides a solid foundation for storing big data and supporting scalability that makes them ideal for usage in a distributed storage. In addition, they scale better for managing multi-media information like x-ray information thus making them ideal for a health-service system. The GIS database referenced patients to given health care specialists or health care facilities given the support for geographical visualization of the information. These requirements and demands are the basis for the Boresha Integrated EHR database system (BIEDS). The hybrid database system complements EHR system that are already in operation, with the overall goal of providing additional functionalities to varied parties in the health care sphere.

IV. Findings and Discussions

The NoSQL databases facilitates intrinsic object orientation, simplicity and APIs (application programming interfaces) that common place programming languages are able to access. A NoSQL database provides a solid foundation for storing big data and support for scalability that makes them ideal for usage in a distributed storage. In addition, they scale better for managing multi-media information like x-ray information thus making them ideal for a health-service system.

The hybrid data storage system combining RDBS and NoSQL complement each other in strengthening EHR system database design and enabling patients to conveniently locate the nearest health-care providers or hospitals based on their preferred search criteria. Further, a GIS database allow healthcare providers to reference patients to given health care specialists or health care facilities given the support for geographical visualization of the information. These requirements and demands are the basis for the Boresha Integrated EHR database system (BIEDS). However, sophisticated data schema, a need for large storage space and loss of hierarchical information may hamper smooth adoption of the BIEDS utility. The hybrid BIEDS database system addresses the shortcomings of the different EHR data set for a properly organized storage offering an efficient access and improved system performance.

System architecture

The Boresha integrated EHR database system architectural framework is shown below: -

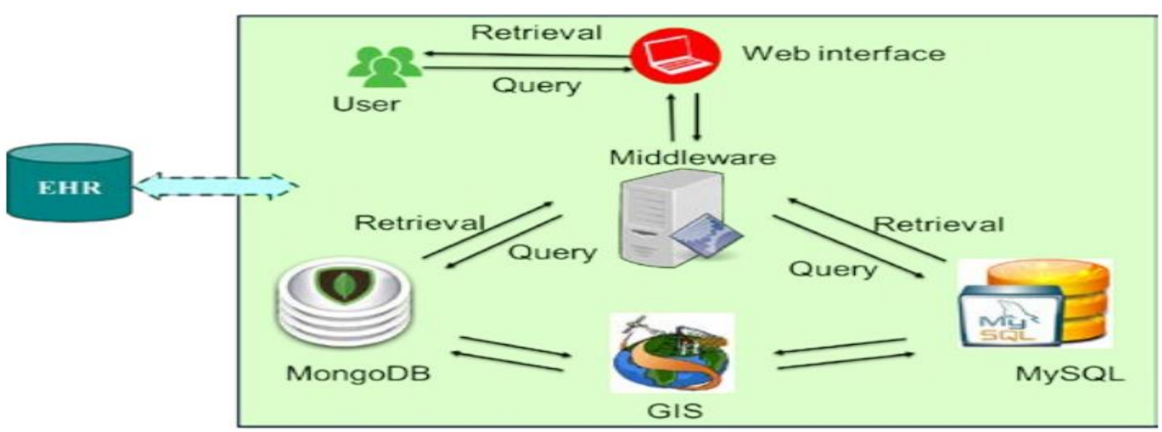

Figure 1 System architecture

Figure 1 above shows the overall structure of the hybrid system. The design encompasses five key components namely MySQL database which is a standard relational database management system, the GIS database instrumental in data visualization, MongoDB which is a NoSQL database, the web based graphic user interfaces to permit querying and retrieving information by end users and the API serving as a communication interface between the back-end databases and the front-end graphic user interfaces.

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The foundation of the entire system is a set of three different database systems, to offer better scalability, performance, and maintenance of the EHR data. The MongoDB manages de-identified documents and semi-structured data for the dynamic and enormous patient clinical visit information. The GIS database developed on quantum GIS, transforms address information into latitude and longitude, providing real-time location information regarding medical facilities and patients alongside displaying relative positions.

The web interface developed using HTML, CSS and Javascript platforms to connect users, MySQL, QGIS and MongoDB databases offers database security accompanied by a role-based authentication scheme, meaning authorized end-users access and retrieving information and generating reports based on their pre-configured security profiles. More specifically, the interface uses a user-friendly graphic user interface to parse a data access query and present results to a user via the web interface.

The middleware API helps in connecting and synchronizing the three database systems using appropriate drivers, implemented in Java, PHP and JQuery. A username and a password would be required to authenticate and allow end-users to interact with the web interface. More specifically, the API shall perform roles such as: Receive data access requests rising from the web-based user interface; Analyze a request and determine if the data requested can be retrieved in MySQL or MongoDB; Generate appropriate SQL statements that match the query; Filter data and limit results just to the requested dataandDisplay the retrieved data to the web interface.

QGIS comes in as a cross-platform open-source geographic information system instrumental for geospatial analysis on the BIEDS data set. Key in the advantages of using QGIS is its ability to consider the environmental factors when doing diagnosis alongside giving an improved view of diseases patterns and epidemiological regions for a large population of the data set. Whenever end users request for visualization, the QGIS updates the search criteria and displays factors for the GIS information.

Elucidation of the Web-Based User Interface:

The development of the Electronic Health Records System (EHR) involved the creation of a web-based user interface to facilitate user interaction with the system. The web-based interface must be designed to prioritize user-centered design principles, ensuring that it effectively serves the needs of healthcare professionals, administrators, and other stakeholders.

User-Centered Design Concepts:

User Persona Development: Before designing the interface, user personas are created to represent the various user groups (e.g., physicians, insurers, nurses, administrative staff) who would interact with the EHR system. This step allows the users to understand their unique needs, attributes and preferences.

User Journey Mapping: A user journey map will be constructed to visualize the user's interaction with the EHR system, from initial login to specific tasks such as patient data entry, retrieval, and decision support.

Information Architecture: The information architecture of the interface must be carefully planned to ensure that users can easily navigate and access relevant information. This will involve the categorization and organization of data and features.

Responsive Design: The user interface to be designed to be responsive, adapting seamlessly to various devices (e.g., desktop computers, tablets, smartphones) to ensure accessibility across different platforms.

Accessibility: Accessibility standards, such as WCAG (Web Content Accessibility Guidelines), are to be adhered to, ensuring that the interface is usable by individuals with disabilities.

Implementation of Usability Testing:

Usability testing plays a pivotal role in refining and optimizing the web-based user interface throughout the development process. The following key aspects of usability testing are to be incorporated:

Test Participants: Healthcare professionals and end-users from diverse backgrounds to be recruited as test participants to ensure a representative sample.

Testing Scenarios: Realistic usage scenarios to be created to evaluate how effectively users could perform essential tasks within the EHR system.

User Feedback: Participants are to be encouraged to provide feedback on their experience, including any difficulties encountered, suggestions for improvement, and overall usability assessments.

Iterative Design: Based on the feedback received, iterative design changes are to be made to enhance the user interface's intuitiveness, efficiency, and effectiveness.

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Final Evaluation: The usability of the interface will be evaluated in its final form to ensure that it meets the usability goals and address any issues identified during testing.

Incorporating these user-centered design concepts and usability testing processes, the web-based user interface of the EHR system will be tailored to meet the specific needs of healthcare professionals while ensuring a seamless and efficient user experience. This iterative approach to design and testing will contribute to the overall success of the EHR system's implementation, resulting in a user-friendly and highly usable tool for healthcare practitioners in Kenya.

Data models

The three database systems –QGIS, MongoDB and MySQL each had feature varied data models.

MySQL database model

To guarantee protection to patients' privacy and ensure data integrity, the relational database management system stores the private patient information alongside crucial health records. These data sets are structured as strict ACID transactions. Figure 2 shows an entity relationship diagram for the data model drawn in the MySQL RDBMS. The main entities are patients, care providers, medical facilities alongside their interactions, inclusive of demographic details which are required by the QGIS database system. The clinical visit entity only stores crucial structured information regarding a visit to allow clinics track operations. Otherwise, the detailed information about a clinical encounter would reside in the MongoDB.

MongoDB data model

Dynamic clinical information plus vital signals encompasses semi-structured and unstructured data. BIEDS integrated system de-defines and manages this data set using MongoDB. The MongoDB NoSQL database system track changes alongside building knowledge base for efficient analysis of data in addition to sharing the very data set with the authorized entities while guaranteeing patient privacy.

Data on clinical visitation was patient specific and typical of service points like lab orders plus measurement results. Occasionally, results of clinical visits commanded the use of imaging data, which is entirely unstructured. The dynamically changing properties coupled with the semi-structured nature of the associated information makes it difficult to save all clinical visit details in a standard relational database management system. Thus, MongoDB offers a better alternative given the need for storage of facility visit data in a document-specific model constituting sub-collections.

Figure 1 shows sample MongoDB data collection model. Essentially, every patient clinical visit generates a single Clinical Visit Document. Similarly, numerous clinical visits for a single patient generate multiple clinical visit documents, related to each other by a shared field patient ID with the visit date as the parameter for distinction. End-users can search and analyze patient clinical visit history, health conditions and physical examination given this design.

Given an ideal facility visitation procedure, a visit might end in varied types of information stored inside the sub collections. Key in the examples of such would include lab orders, lab test results, prescribed medication along with the risk factors around specific ailments. Every collection could present varied types of sub collections, and at some point, even sub-collections within a collection will vary. For inside a lab order sub-collection has lab test results as sub collection within it, and at some point, even the parameters for measuring the laboratory test results might end up varying over time.

Enforcing database security

A regular user of the BIEDS system shall not have a direct access but instead have an application-level user profile to permit access to the information in the database system via a web browser. The web-based user interface validates any activity before granting access to the database. Varied user categories permit varied access privileges. The BIEDS system implements a combination of fine-grain database access and role-based authentication model. Varied users have varied privileges when accessing the database, for instance, administrators have access to the entire data whereas a patient account permits access only to their prior care seeking patterns, including that of minors associated with them. Physician accounts command a second layer of validation and authorization.

Data Flow Diagram

The data flow diagrams for the Boresha integrated EHR data system is as follows:

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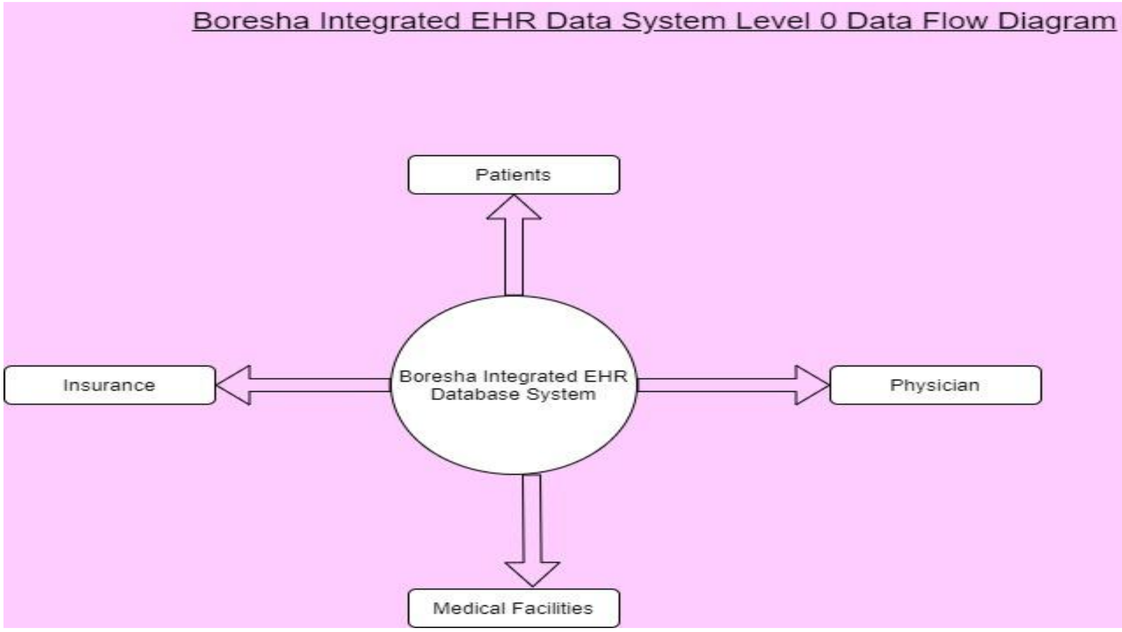

Figure 2 Level 0 Dataflow diagram

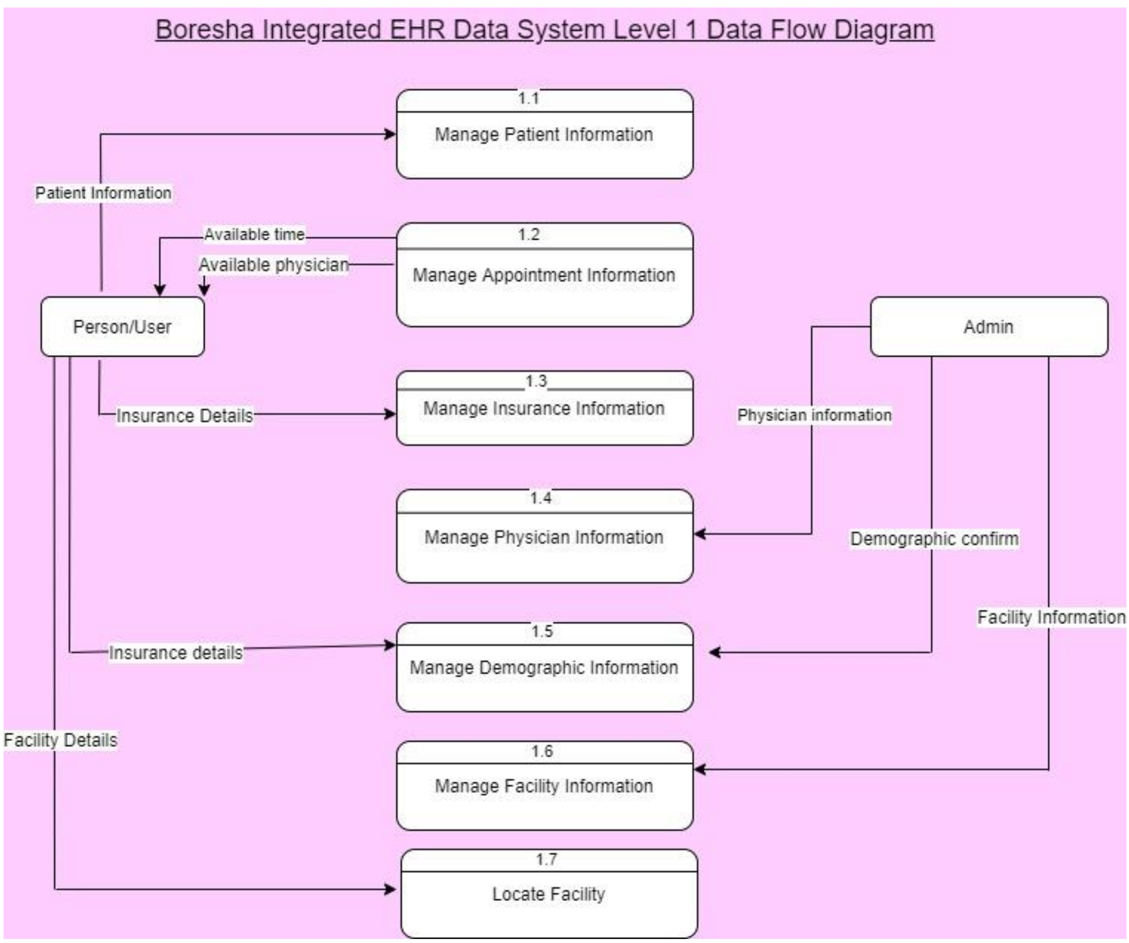

Figure 3 Level 1 Dataflow diagram

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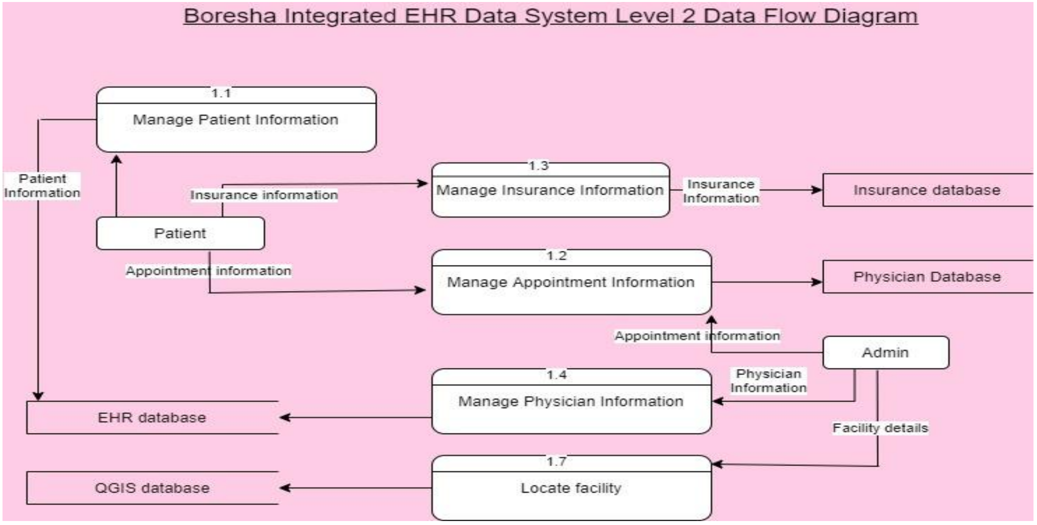

Figure 4 Level 2 Dataflow diagram

Entity Relationship Diagram

Figure 5 below shows the entity relationship diagram for the MySQL used in the BIEDS

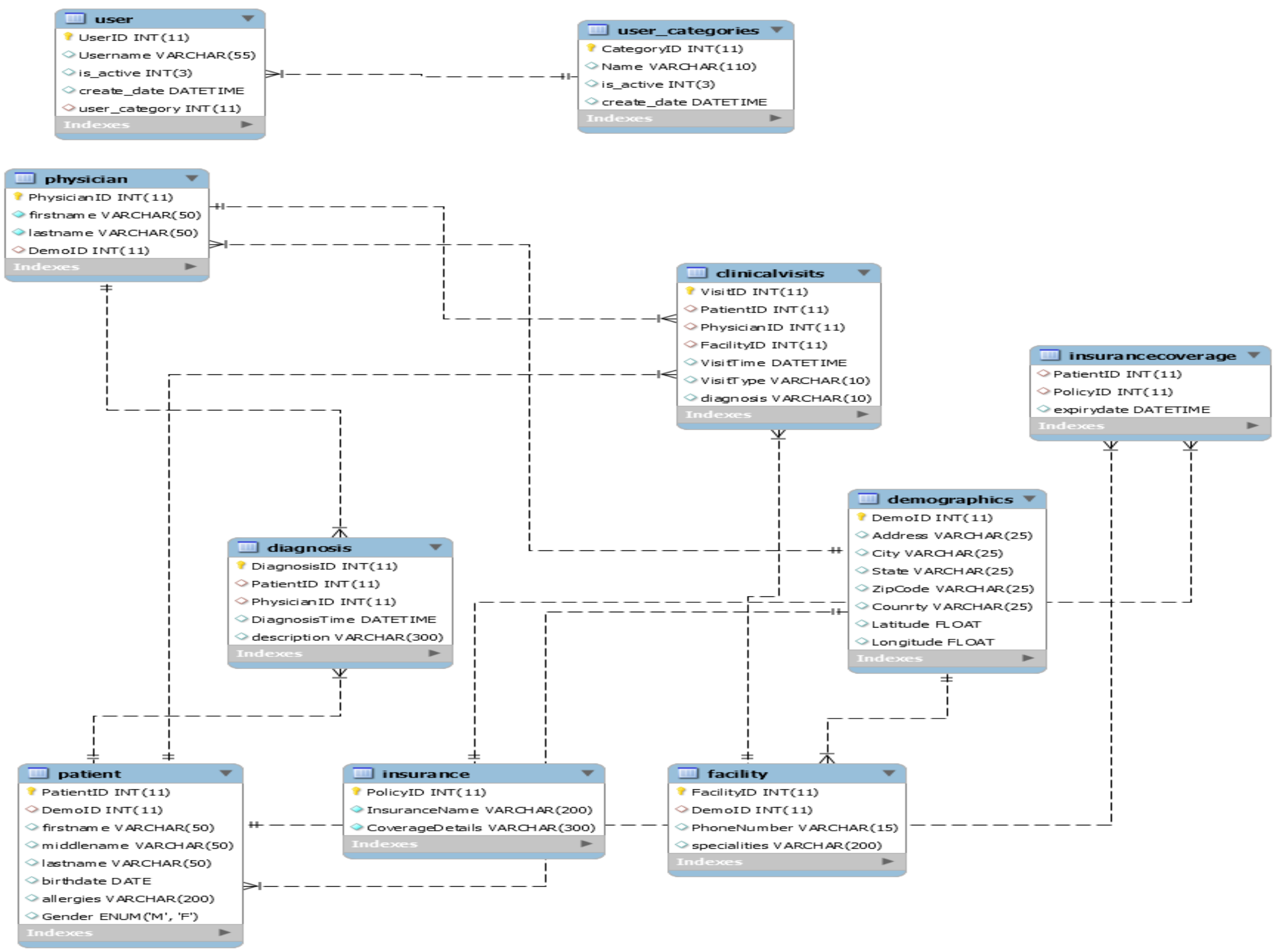

Figure 5 Entity relationship diagram

Empirical Validation

To acquire empirical data on the performance, scalability, and user experience of the proposed hybrid Electronic Health Record (EHR) system, it is imperative to conduct real-world implementations or simulations. This critical phase of the research aims to validate the efficacy of the hybrid EHR system in real healthcare settings. The primary objectives of this phase are:

Performance Assessment: The real-world implementation or simulation will involve the deployment of the hybrid EHR system within healthcare facilities in selected areas in Kenya. We will measure its performance in terms of response times, data retrieval speeds, and system reliability. By collecting empirical data, we aim to demonstrate the system's ability to handle real-time data input and retrieval efficiently.

Scalability Testing: As healthcare databases can grow exponentially, assessing the system's scalability is crucial. We will simulate scenarios of increased data volume and user loads to determine how the system scales. This empirical data will inform us about the system's capacity to accommodate growing healthcare databases without compromising performance.

User Experience Evaluation: User experience is pivotal in healthcare technology adoption. We will engage healthcare professionals and end-users in real-world settings or simulated environments to gather feedback on their interactions with the hybrid EHR system. Usability assessments, user satisfaction surveys, and feedback on user-centered design will be integral to this evaluation.

Data Security and Compliance: Additionally, during real-world implementations, we will closely monitor the system's adherence to Kenyan government data, information and privacy, and HIPAA EHR standards and data security protocols. Ensuring compliance with these critical healthcare regulations is fundamental to maintaining patient data privacy and integrity.

V. Conclusions

The hybrid BIEDS database system addresses the shortcomings of the different EHR data set for a properly organized storage offering an efficient access and improved system performance. The NoSQL databases facilitate intrinsic object orientation, simplicity and APIs that common place programming languages are able to access. Further, the hybrid data storage system combining RDBS and NoSQL complement each other in strengthening EHR system database design and enabling patients to conveniently locate the nearest health-care providers or hospitals based on their preferred search criteria. Equally, a GIS database allow healthcare providers to reference patients to given health care specialists or health care facilities given the support for geographical visualization of the information. The hybrid BIEDS database system addresses the shortcomings of the different EHR data set for a properly organized storage offering an efficient access and improved system performance.

Author About

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