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Research Paper

Design of a Smart Integrated Medical Information and Decision Support System (SIMIDSS), using readily and commonly available resources.

[1] Chinedu .I. Onwuegbuna and [2]Hyacinth C Inyiama
[1] Electronic and Computer Engineering Department, Nnamdi Azikiwe University, Awka, Anambra State
[2]Electronic and Computer Engineering Department, Nnamdi Azikiwe University, Awka, Anambra State

Abstract
The hospital Information system (HIS) is vital in the health sector because it has the prospect of improving the quality, cost and safety level of the health care given to patients. However, the various implementations of HIS especially in developing countries have not been as successful as anticipated. This work is a unique attempt to use the concepts derived from Management Information Systems (MIS) and Decision Support Systems (DSS), alongside readily and commonly available resources to develop an efficient, seamlessly integrated, cost effective and scalable Smart Integrated Medical Information and Decision Support System (SIMIDSS). The developed SIMIDSS was suitable for use for real time hospital operations as well as for historical clinical documentations. The SIMIDSS developed reduced to a minimum; the server resource availability issues associated with server-client HIS design as a result of database record locking mechanism it uses to ensure data integrity.
Keywords: *Hospital Information System, Decision Support Systems, Data-Repository, Server-Client, database*

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I. INTRODUCTION:

Management Information System (MIS) is a division of Industrial Engineering and Information Management that deals with the use and bringing together of People, Information, and Information Technology to assist individuals in performing the tasks related to management and information processing (Subbiah et al, 2016). MIS deals with the planning for, the development, management and use of information technology tools to help individuals perform all information processing and management tasks (Haag & Dawkins, 2000). MIS is an information system application that uses analytical processing to generate reports with a prearranged format, which are periodic and predetermined summarizations of the information from a database and conveys the same to whoever needs it (Whitten et al, 2001).

A Decision Support System (DSS) is a type of information system application that provides its user with decision-oriented information whenever a decision making situation arises (Whitten et al, 2001). The prime objective of DSS is to support a human decision maker at some stage in the process of arriving at a decision (Zwass, 1998). DSS strong point is in its ability to support decision making in scenario where both the power of the computer and human judgment are necessary, especially when ill structured and semi structured problems are approached in which part of the decision process usually requires a significant amount of computer support. The computer support here implies the use of analytical models, database access, together with human judgment; all these are injected at vital junctures to arrive at a decision. (Zwass, 1998).

Health Information Systems (HIS) are complex and comprehensive Integrated Management Information Systems designed to manipulate, store and retrieve both administrative and clinical information to support the all-inclusive information requirements of a hospital (Khalifa, 2014) and (Acharyulu, 2012). HIS is made up of the integration of different software such that data and information can be captured and disseminated to the various sections of the hospital as required. HIS can be made to manage the daily medical services work flow as well as make easy clinical and administrative data management (Balaraman and Kosalram, 2013). It is intended to provide the needed information to each section and level of operation at the right time, in the right place as well as in the right form (Ajami and Zohreh, 2012). It can be deduced from these that a HIS is a vast comprehensive combination of information systems seamlessly and harmoniously integrated for the purpose of effectively and efficiently supporting the clinical and administrative activities of a hospital alongside providing for the hospitals comprehensive information needs.

In spite of the fact that the HIS possesses the potential to improve the quality, safety level and costs of health care delivery, most of the various HIS implementations especially in undeveloped countries have not been so successful (Khalifa, 2014). Factors affecting HIS implementations include the expensive nature of the venture, The high cost of hardware and software, the staff training requirements, network and licensing expenses, staff resistance to change, the lack of usability of most HIS systems because the system's processes does not fit into the existing hospital work flow (Shailendra S, 2019), Lack of technical expertise and resources, and lack of appropriate planning.

Adequate planning is needed for successful implementation of HIS and care taking to make certain that the objectives of the health establishment are met (Sinha and Kurian, 2014). Again HIS implementation usually comes with organizational cultural changes. These changes must be planned for and all stake holders must be committed to it. Furthermore, the design, development and implementation of a HIS should be driven not only by the apparent routine information requirements but also to be taken into consideration is the resource availability and constraints. (Kleinau, 2000). The success or failure of a HIS implementation to a very large extent is determined by resource constraints, (Kleinau, 2000). Traditionally, most HIS are supported in Client Server architecture. This utilizes a connection based data access that keeps database connection open until the user connected to the database is properly logged out. Although this provides a fast system response as required in such a life critical system, it suffers the drawback of system unavailability to other users whenever one user is already connected to the database for data operations. The web alternative HIS design scales well with multiple concurrent users because of the disconnected data access it uses, however, the response time and predictability of performance is not ideal for a life critical system like the HIS especially in areas without robust internet infrastructure. Although HIS software are available in the market, many of these Off-The-Shelf HIS require a high implementation, running and maintenance costs. Again, most of these systems cannot be simply put to use outrightly, but instead will require a lot of intricate, time consuming harmonizing changes, adjustments, and adaptations before they can be put to use, (Khalifa, 2014). It is noteworthy to point out that because the requirements and resources differ from place to place, no two HIS are comparable (Kleinau, 2000). HIS ought to be custom made so it will fit into the hospital's operational workflows, (Shailendra, 2019)

This work is a distinctive attempt to use concepts derived from MIS and Decision Support Systems (DSS), in conjunction with readily and commonly available resources to develop an efficient, seamlessly integrated, cost effective and scalable Smart Integrated Medical Information and Decision Support System (SIMIDSS) that is tailored to match the work flow of the Delta State University Abraka's health center, in Nigeria. The Delta State University health center maintains her health records on papers stored in files and stacked in shelves. This record keeping approach is inefficient and error prone. To deal with this problem, this work aims to develop the SIMIDSS. The developed SIMIDSS so will implement disconnected data access architecture on a client server (rich client) system to improve the server resource availability and should be easy to deploy, use, and maintain. SIMIDSS will also be interactive, reliable and suitable for use in both real time hospital operations as well as for historical clinical documentations. The SIMIDSS is a unique approach to the hospital record management. It should enable the different health care workers to perform their various duties from their various offices and or any office connected to the SIMIDSS. The User-groups/roles covered in this work includes the Doctors, Nurses, Medical Laboratory Scientists, Scan/Radiology Scientists and Administrative/Personnel Staff.

The SIMIDSS will capture, integrate and centralize the hospitals records, streamline patient information flow and its accessibility to the doctors and other health workers. It will enable the clinicians' access and work with a patient's information to achieve the best possible quality of health care service.

The SIMIDSS will capture and document the Doctors consultation notes (for inpatients and outpatients) , the various test requests made on patients, the test results alongside information on the staff that carried out and supervised these tests, the Nurses patient documentations (including Nurses patient admission summary, the admitted patient's day to day drug, fluid and temperature documentations e.t.c). All these details will be appropriately tagged to the patient records and made available whenever the patient's medical information details are needed. Legibility issues and other medical errors will be minimized

II. MATERIALS AND METHODS:

The Microsoft Access Relational Database Management System (RDBMS) was used unconventionally as the building block to develop the (SIMIDSS) Data Repository. The Microsoft ActiveX data Objects (ADO), a Microsoft's strategic Application-Level Programming Interface was used to access the information in the SIMIDSS Data Repository. Microsoft Visual Basic Programming Language was used to develop the User Interface as well as the process controlling routines. The Computer and Network System Requirements are:

- o For the Server unit Housing the SIMIDSS Repository

- Monitor Unit (VGA or higher resolution)
- Processor Unit (4 GHz or faster speed)
- Random Access Memory (1 GB or higher)
- Hard Disk Size (250 GB or more)
- Operating System: Windows Server 2003 R2 (X86 and X64), 2008, 2008 R2, Windows XP (service pack 2 or 3)

o For the Client Unit Housing the SIMIDSS software

- Monitor Unit (VGA or higher resolution)
- Processor Unit (2.6 GHz or faster speed)
- RAM size (512 MB or Higher)
- Hard Disk Size (80 GB or more)
- Operating System: Windows XP (service pack 2 or 3)
  Windows Vista
  Windows 7

o For the Computer Systems Networking

- Router
- Network Switch 10/100Mbps
- Category 5 Local Area Network (high speed network cables)

The Shell (SPDC) Information and Communication Technology (ICT) Center, Delta State University, Abraka, Site 3 was used for software testing and performance evaluation.

The Top-Down approach was applied in the design of the SIMIDSS to breakdown the overall software structure into smaller more manageable sub systems and sub control systems as shown in Figure 1, Figure 2 and Figure 3 . These resulting subsystems from the SIMIDSS software decompositions had definite inputs and outputs, but no specific internal structures.

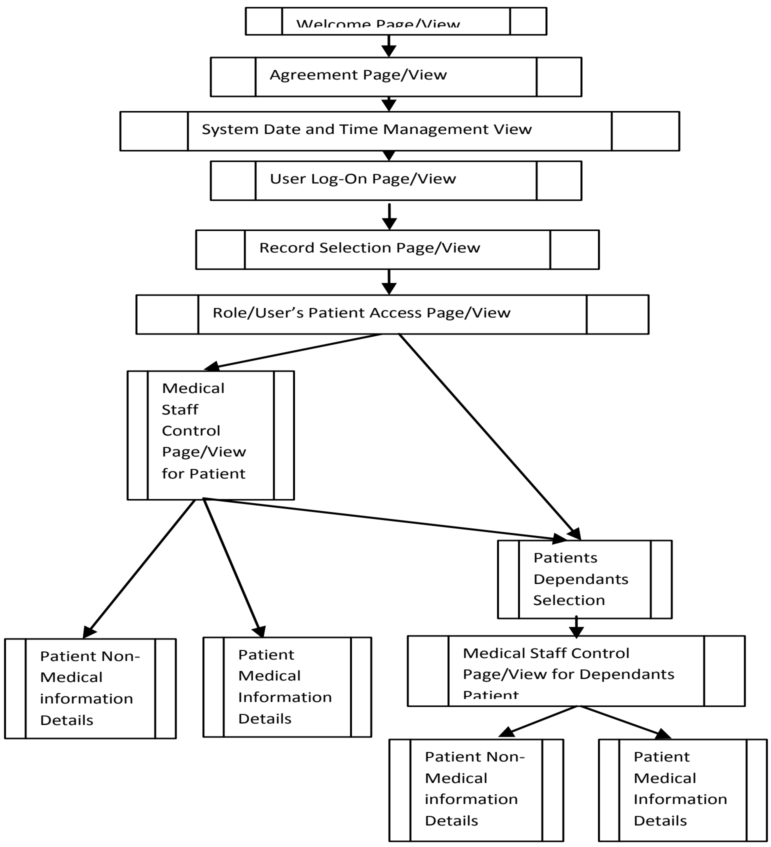

Figure 1. (SIMIDSS) Top-Down Design Approach Block Diagram

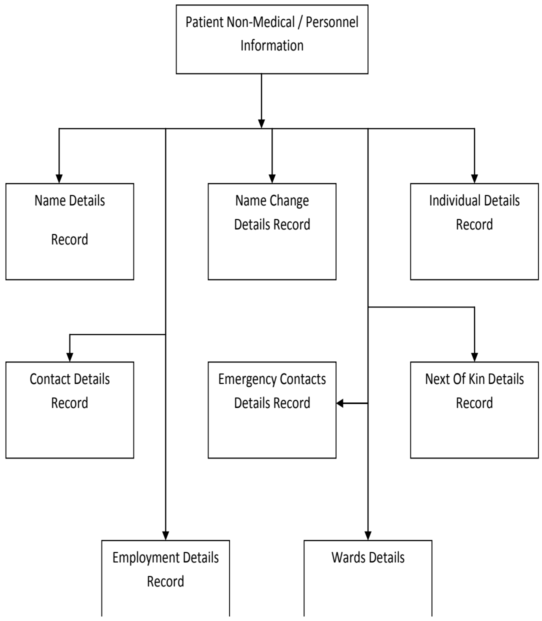

Figure 2. The SIMIDSS "Patient Non-Medical / Personnel Information" Diagram Expanded

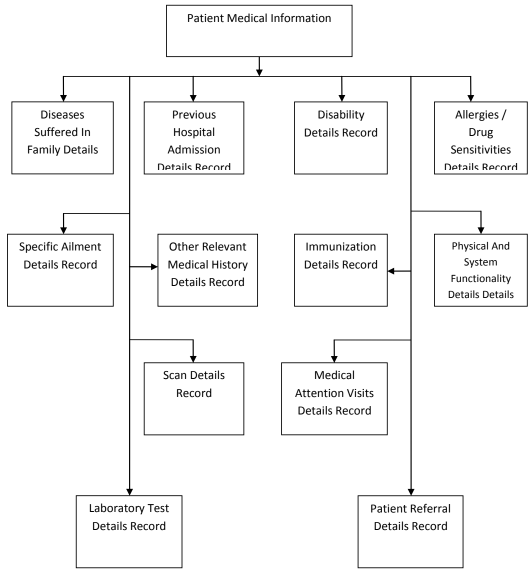

Figure 3. The SIMIDSS "Patient Medical Information" Diagram Expanded

The Modified Water-Fall development approach (sometimes called the Verification and Validation approach or the V-Model approach) was applied in the development of the internal details of each of subsystem that resulted from the initial SIMIDSS software decomposition. Each individual software development stage was associated and matched with a corresponding testing phase, i.e.

- o The Business Requirement analysis stage was matched with Acceptance testing phase.
- o The System design Stage was matched with System testing phase.
- o The Architectural design Stage was matched with Integration testing phase.
- o The Module design Stage was matched with Unit testing phase.

The SIMIDSS was designed to be compatible with the Delta State University, Abraka health center's work flow with the following characteristics:

- Easy to use (user-friendly) information system
- Simple to understand system
- Cost effective to deploy (not requiring expensive hardware)
- Easy to run and maintain
- Will not require specialized staff
- To be developed using commonly available resources
- Use a data repository arrangement that will be easy to manage and maintain without incurring recurring license fees.

The SIMIDSS was designed to setup a temporal dataset automatically on the client computer whenever a user accesses a patient record. This temporal dataset will comprise all records on that patient under a particular topic. This is where the user interface will read data from when the user is perusing through the patients record (under that topic). This will reduce the number of times a user needs to connect to the repository for data read.

A study of the information needs of the University's health center was carried out, working with the Unit Heads of the health center. The study was carried out in three phases namely:

a. Problem analysis phase
b. Requirement analysis phase
c. Decision analysis phase.

The first phase of the analysis was aimed at properly understanding the health centers needs. The second phase was aimed at identifying and specifying the data, process and interface needs of various the users of the SIMIDSS. At this point, no specific technology details brought in. The third phase of the study involved investigations into several different approaches to develop the needed system so as to meet the stated requirements. At the end of the system analysis, a list of business requirement statements and system improvement objectives was produced.

Data / Information Repository Requirements: The SIMIDSS, data repository was designed to **be integrated** i.e. (the repository should be centralized and consolidated such that it integrates data/information derived from the entire Health Center), **be subject oriented** i.e. (the data organization must be done by topic, each topic containing specific subject of interest), **be time variant** i.e. (once updates are made to the repository, all time-dependent aggregations are also updated/recomputed), **be non-volatile** i.e. (once entries are made to the repository, they are not to be removed), be capable of supporting very large data volumes as well as be cost effective to implement, run and maintain.

The User Interface was designed to place the user in control, reduce user's memory load and be consistent.

III. RESULTS AND DISCUSSION:

The SIMIDSS was designed and developed as a Server-Client system that is capable of supporting very large data volumes. The SIMIDSS software (a rich/thick client) runs on the client system while the data repository runs on the server system. The User Interface was designed to put the user in control. The user interface contains visual clues so as to assist in reducing the user's memory load. The SIMIDSS was designed so that its processes match the health center's work flow. The SIMIDSS repository was developed as a homogenous virtual repository that is an ensemble of independent identical database files that are addressed and coordinated by routines on the application layer. These independent identical database files are named such that their individual names facilitated their addressing and referencing. The SIMIDSS utilized the disconnected data connection access. The SIMIDSS was tested over a computer networked environment, a local area network (LAN) capable of data speed of up to 100Mbps for the client systems connected using category 5 (CAT 5) network cables and 54Mbps for clients connected using wireless access. A typical working session of the University Health Center was simulated and the SIMIDSS put to test. It was observed that there was ample availability of the repository resources to the users even with concurrent users. The combination of the decentralized processing approach, the disconnected data access and the temporal cache used in the SIMIDSS design all contributed to reduce significantly the server resource unavailability usually experienced with typical server-client HIS during concurrent usage due to database locking,.

The client computers connected via the CAT5 cables were slightly faster in response compared to those connected via wireless access. This can be attributed to the higher network latency of wireless connections when compared to that of wired connection

There was no need for a relatively large and complex server system because most of the needed processing was done on the client computers. The server unit's central processing unit (CPU) usage/load was minimal.

Additional client computer systems could be added to the already connected client computers without significant degradation of performance with respect to the system's response time.

The SIMIDSS client software interactions with the SIMIDSS repository were seamless.

The users (staff from the health center) easily adapted well to the SIMIDSS partly due to the user friendly interface and also the similar work flow.

Some screenshots of the SIMIDSS User Interface are displayed below: Figure 4 is a screenshot of the SIMIDSS User login view; Figure 5 is the SIMIDSS Record Selection view where the user selects the staff or student patient group. Figure 6 is the SIMIDSS patient identification view where the user specifies the particular patient he or she wants to attend to. Figure 7 is the Staff Control View for patient record. This is from where the user can access the patient records that he or she has the permission to access. Figure 8 is the SIMIDSS Doctors' patient consultation view.

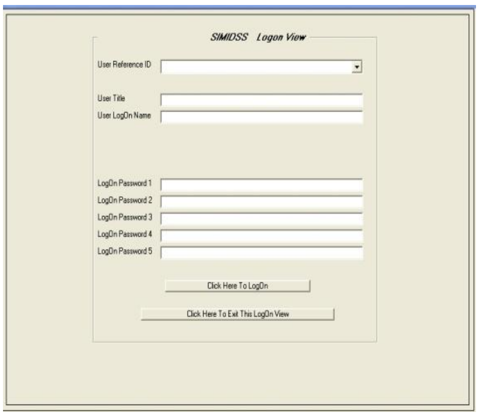

Figure 4. SIMIDSS User Log-On View

Figure 5. SIMIDSS Record Group Selection View

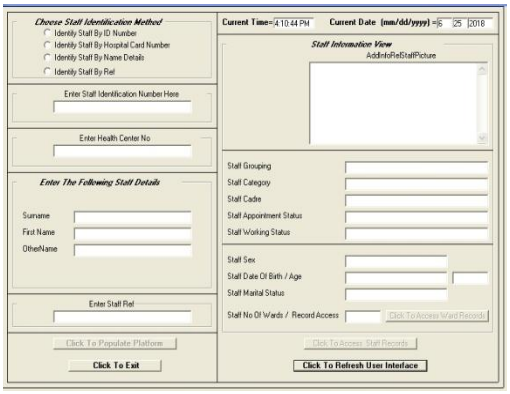

Figure 6. SIMIDSS Patient Identification View

Figure 7. SIMIDSS Staff Control View for Patient Record

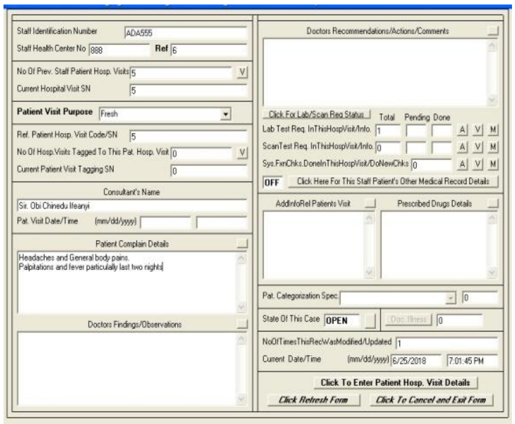

Figure 8. SIMIDSS Doctor's Patient Consultation View

This study shows an approach to HIS design and development that eliminates the recurrent license fees for database, reduced hardware requirements, improved system availability, using commonly available resources. When compared with most HIS developed with the traditional server-client approach, there was ample availability of the server system resources to other users. This can be attributed first to the non persistent connection approach to data access used in the SIMIDSS design. Secondly, to the rich client design of the SIMIDSS that resulted in that most of the processing was done at the client system that only connects to the data repository for data operations. This made each user experience almost instantaneous response from the system as though he or she alone was connected to the repository. Again because of the decentralized processing approach adopted in the SIMIDSS design, most of the processing is done on the client computer. The work load of the server machine was reduced greatly, thereby reducing the needed computing power at the server end. This implies that a relatively large and complex server system is not needed. This can translate into reduced hardware costs. Additional client computer systems can be added to the SIMIDSS without significant effect on the systems response time. This can be attributed to the fact that most of the processing power requirements needed for each additional client computer was provided by that particular client computer that was added.

IV. CONCLUSION:

This work demonstrated how a functional Smart Integrated Medical Information and Decision Support System can be cost effectively developed relying solely on the commonly and readily available resources like a free inexpensive RDBMS database systems, etc. It can be seen how a data repository that is capable of supporting very large data volumes can be cost effectively developed.

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