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A WEB BASED APPLICATION FOR CLINICAL LABORATORY INFORMATION MANAGEMENT SYSTEM

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Abstract: Continuous progressive wheel resulted in scattered plans of the major objective to climb the ladder of success within a very short period of time. Within past years, Electronic Health Records (EHR) have been realized due to the growing number of hospitals worldwide. EHR systems can be in different forms, that refer to a wide range of electronic information systems used in healthcare. Medical institutions that might use EHRs are hospitals, pharmacies, general surgery practices, and other health care professionals. Clinical or medical coding is an important process to transform medical documents such as laboratory or radiologic results beside physician notes into universal alphanumeric codes that represents the medical diagnosis, procedure, service, or equipment. As archiving process is an important part of the clinical lab, besides searching for related information or previous tests' results are boring work and in order to make this process easier, faster and accurate, this paper proposed the design and implementation of a web-based clinical laboratory management system, in which only authorized systems' users such as lab assistant or physician can access patients' records in order to ensure that the whole process is secure, accurate and reliable. This system is developed using MySQL for database design and PHP, html, CSS and JavaScript for user interfaces.

Keywords: *Web-based Application, LIMS, Clinical Laboratory, Database Management System*.

Introduction

Administration requires monthly reports related with income, the requested tests, etc. Currently, this is done manually by entering details followed by printing reports and delivering them to the associated centers by hand. But this process is time consuming mostly and report delivering is delayed due to many reasons such as traffic. This has become a major concern for electronic health care.

In some critical situations, doctors need to check the history of their patients' tests, such as sugar, cholesterol, urine, tissues etc. that might be lost. Therefore, it is very important to save records of the regular patients at their medical center. Besides, providing patients with their previous reports may be an advantage for case diagnosis, treatment and prevention of diseases [1]. Through general research area concerns the healthcare information system, many clinics and labs still use the traditional way in storing patient information such as paper cards used within Laboratory Information Systems (LIS) and Electronic Medical Record (EMR) [2]. This

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kind of keeping is impractical because it needs space for storage and time in searching for a specific information. In medicine, as in many other fields, there is a notable gap between science, practice, and education. The main reason for this situation is that scientific research is introduced into the treatment process very slowly, even information technologies are effective in solving the existing problem [3]. However, nowadays most industries are using the Internet and Web applications to proceed their businesses productively [4]. Medical centers and labs can also make their service more productive by automating their processes [1], which contributes remarkably to the overall care given to patients [5]. A computerized Laboratory Information Management System (LIMS) is evolved to collect, record, arrange, display, back up results and manage the laboratory finances in a suitable way [6]. An efficient LIMS will reduce the burden on the laboratory technician on having to record all the patient details, which is a time-consuming task [4]. In addition, a well-planned and installed LIMS makes the data flow accurately and accessibly in the clinical laboratory.

LIMS important elements are data protection, confidentiality and effective reporting system. For computerized systems as the one proposed in this paper, systematic backup operations are required besides preserving patient's privacy by applying security policies to protect the laboratory data, as hospitals and clinics connect their Local Area Networks (LANs) to the Internet [7]. Lab report, is the final lab result that must be accurate, legible, easily understood and issued in time [6], releasing patient test results requires an authorization process by the patient [7].

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1. Related Work

Prasanna implemented a hope diagnostics medical laboratory service using MS Excel sheets for report printing besides a computerized system o for the payment transactions. The process involved entering details and getting results of each patient one by one with the excel sheet [1]. Gaponova proposed an appropriate software to improve doctors' performance. Furthermore, an important aspect of making a unified database of the electronic health records and provides this extensive information in hospitals, hence creating the need to evaluate various ways in which the Russian healthcare system can be improved regarding records keeping [3]. Storch et al demonstrated the automated export, aggregation, and analysis of infectious disease diagnostic test results from clinical laboratories across the United States in a secure manner. They proposed a system that could aid in monitoring the seasonal occurrence of respiratory pathogens and may have advantages with regard to scope and ease of reporting compared with existing surveillance systems [7]. Yang et al created a model to explain the stages of IT evolution in the healthcare sector, incorporating initiation, contagion, control, and integration stages. The model was evolved focusing on healthcare IT in Singapore, according to Singapore's advanced IT and medical infrastructure and relatively lower spending on healthcare unlike other developed countries [8].

2. LIMS Advantages

There are many issues taking into consideration in concerning the electronic health systems, such as every medical center that is set up in different ways according to its functions. Some centers have integrated architectures such as the Lab Information System (LIS) embedded with

the EMR. Most other centers use an interfaced architecture [2].

A computerized clinical laboratory has the capability to manage, analyze and retrieve data quickly and smoothly. It provides a number of advantages over paper-based systems. Some of these advantages are:

1. Decreasing errors: a proper system will notify the user about data inconsistency. As a result, errors are reduced.
2. Managing quality control: it becomes convenient keeping a good quality control records and creating statistics automatically.
3. Facilitating data searching: a variety of parameters are used for data retrieval; as it is possible to access data by patient name, number or test result, which is a strenuous task with paper-based systems.
4. Accessing patient details: most computer systems allow accessing the latest laboratory data for each patient to compare the most recent results against previous once.
5. Releasing reports: it becomes quite easy to generate comprehensive and obvious reports quickly.
6. Tracking reports: a computer system makes it easier to track tests and delivering reports as they are completed to the related patients.
7. Tracking and analyzing trends: as the system provides powerful search abilities, it can be used effectively in retrieving and analyzing various trends.
8. Keeping patients' details confidentiality: it is easier to keep the laboratory data in a confidential manner unlike the handwritten reports.
9. Financial management: the proposed system offers perfect financial management for preparing bills and purchasing lab tools.

3. Proposed System Design

At the designing stage, an imaginative construction of the system is done using one of the designing techniques for developing the system. The design describes a high level view of the system. Firstly, start with database design; the stages of the database system development lifecycle are as follow:

I. Database planning: Planning how the lifecycle phases are recognized conveniently.

II. System definition: stating the database system scope and limits, including physician user views, with his related users and application fields.

III. Requirements collection and analysis: collecting and analyzing all information about the clinical laboratory. During this phase, the database designer meets the potential system users to understand and document their requirements. The collected and analyzed Lab documents are patients, doctors records, tests normal values with their prices, bills, purchase invoices, lab tools, chemical materials that are necessary for the lab daily work, etc. The outcome of this step is a set of users' requirement as follow:

1. The ability to add and edit doctor and patient information.
2. Add new system users and edit their information.
3. Add new tests and modify the normal ranges and prices as needed.
4. Keep an archive for each registered patient, which serve as part of a patient healthcare history besides comparisons between current and previous tests

easier. This archive would be kept for a certain interval according the lab policy.

5. Once the test is printed and/or delivered to the patient and/or requested by doctor(s), the test results should not be altered since it becomes as part of the patient archive.
6. The patients' personal information with their tests is kept securely, so that only authorized system users can access their records to maintain privacy.
7. Provide monthly, weekly and daily statistics about the number of patients, number of tests, payments, etc.
8. Record all the laboratory needs such as lab tools, chemicals, autoradiography film, tourniquets, organizers, consumables and specimen handling to be ordered and purchased.

IV. Database design: Database design is the process of producing a detailed data model of a database, consists of three main phases: Conceptual, logical and physical design of the database.

a. Conceptual database design: The conceptual schema is a description of the users' requirements. As these concepts do not include implementation details, they are usually easier to understand and is used to interact with nontechnical users. The conceptual schema can be used as a reference to ensure that all requirements are met and do not conflict. Figure (1) shows the conceptual schema diagram for the proposed clinical laboratory. As indicated there are nine entities, Doctor, Patient, Physician, Bill, Report, Test, Test_Group, Lab_Type and Purchase. A doctor is responsible for many patients but a patient is related to one or many doctors. A patient may have many bills while a bill belongs to one and only one patient. A bill may contain many tests (at least one) and a test may be included in one or many bills. A report includes one and only one bill while a bill may be contained in zero or one (and only one) report. A test group may contain many tests while a test belongs to one and only one test group. A lab type may contain many test groups while a test group belongs to one and only one lab type. A physician prepares many bills while a bill is prepared by a one and only one physician. A physician make many purchases while a purchase is prepared by a one and only one physician.

b. Logical database design: the conceptual data model is mapped into a logical data model in this phase. The resulted model is approved to ensure structural appropriateness and support for the required transactions. An algorithm described in [4] is applied for ER-to-relational mapping. The resulted clinical lab relational database schema is indicated in figure (2).

c. Physical database design: the base relations, file design organizations, and indexes used to fulfill efficient access to the data with an integrity constraints besides the security measures are done at this phase. All those steps are applied on a secondary storage.

V. DBMS selection: a convenient DBMS for the proposed database system is chosen at this phase. Relational DBMS (RDBMS) is a common selection for the storage of information in new databases used for financial records, manufacturing and logistical information, personnel data, and other applications. In the proposed system, MySQL is used as RDBMS.

VI. Implementation: Creating the physical database definitions and application programs.

VII. Data conversion and loading: Loading data from the old system to the new one, and if possible converting any existing applications to run on the new database.

VIII. Testing: Database system is tested against errors and validated according user requirements.

IX. Operational maintenance: The system is monitored and preserved continuously, the new requirements are integrated into the database system through the preceding stages of lifecycle.

The main users in the proposed LIMS web application are doctor, physician and patients. Patients' activities are represented with sequence diagrams as shown in figure (3). As doctor is responsible for specifying the required lab tests for patients and checking the results, therefore, his sequence diagram is almost same as the patients' diagram except his access to the test database for selecting the necessary tests. Physician activities are represented with sequence diagrams as shown in (4). Sequence diagrams illustrate the interaction among classes in terms of exchanging the messages over time. They are a good method to validate and explain various runtime scenarios, which show how a system will function and how to obtain responsibilities a class may need to have within the process of modelling the new system.

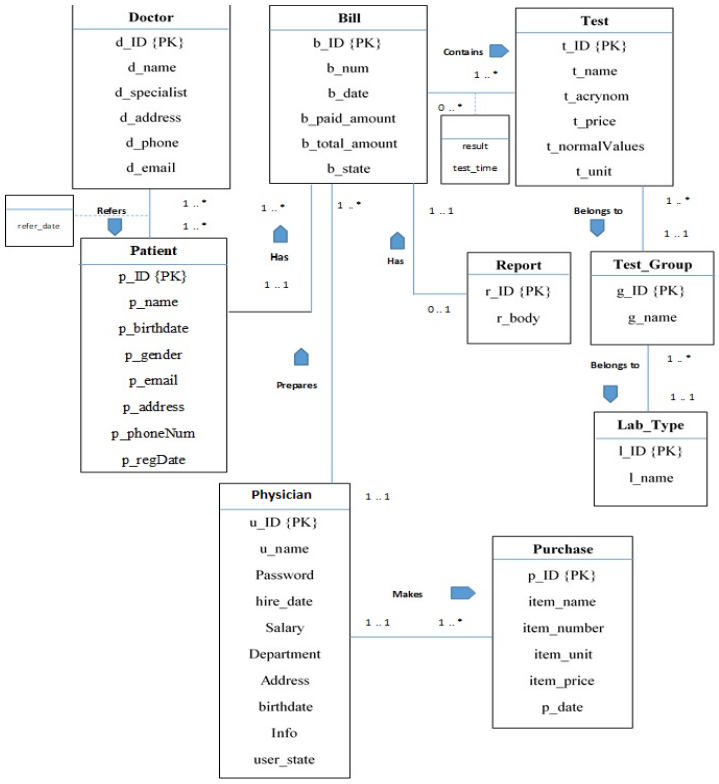

Figure 1. Conceptual schema diagram for the proposed LIMS Web Application

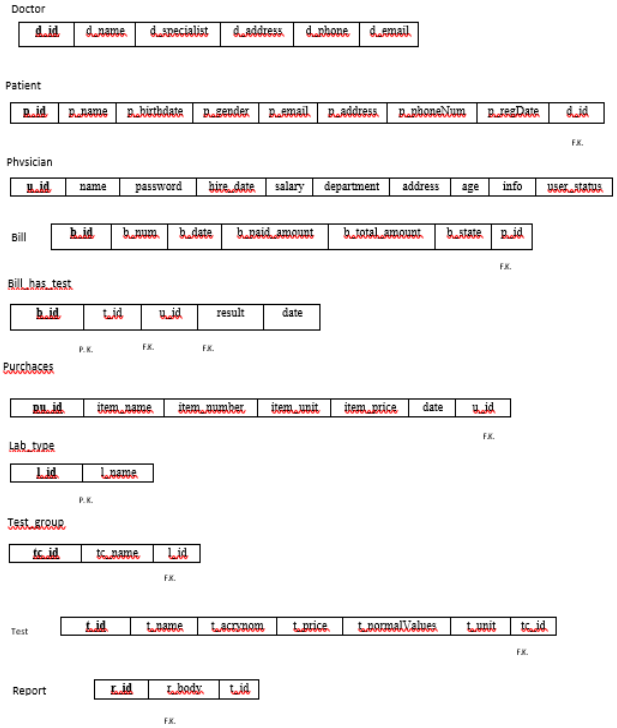

Figure 2. Relational Database Schema for the proposed LIMS Web Application

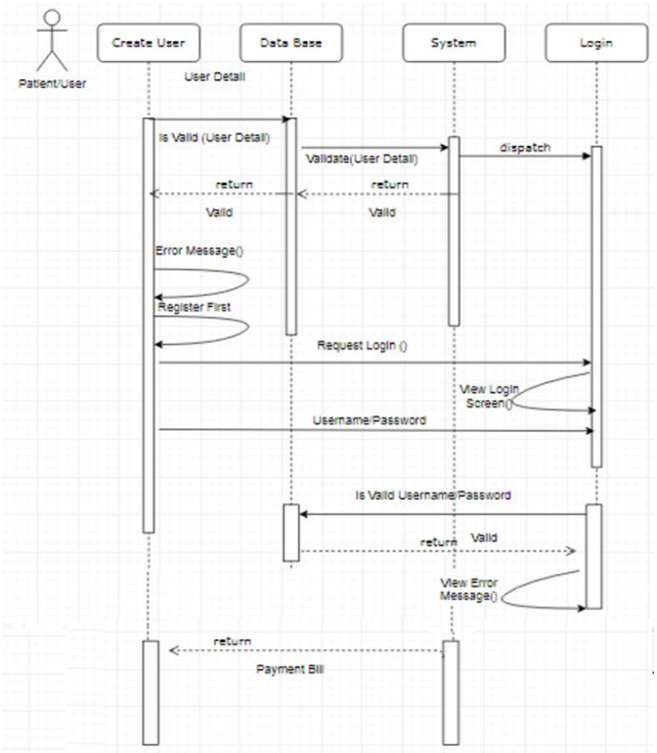

Figure 3. Patient Sequence Diagram

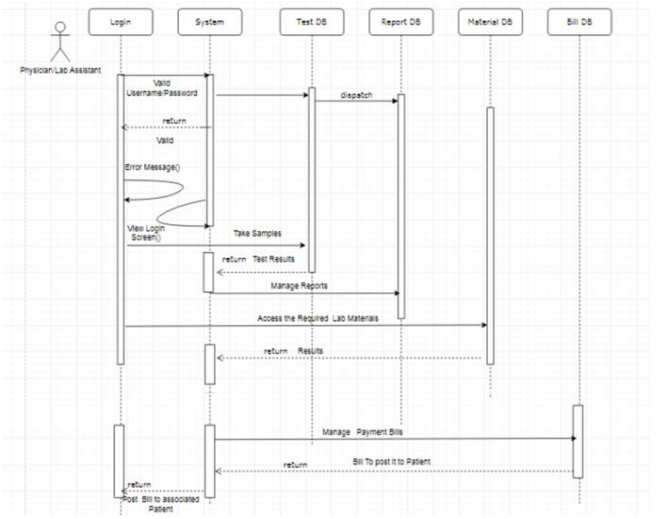

Figure 4. Physician Sequence Diagram

User interface design or user interface engineering is the design of websites, computers, machines, mobile communication devices, and software applications with the focus on the user's experience and interaction. The goal of user interface design is to make the user's interaction as simple and efficient as possible. Figure (5) summarizes the data flow diagram of the proposed LIMS system.

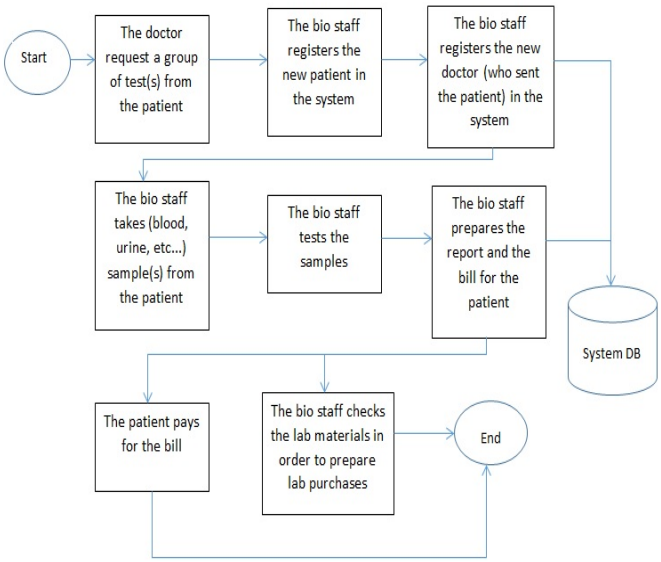

Figure 5. LIMS Data flow Diagram

4. System Implementation

Software implementation encompasses all the post-sale processes involved analyzing requirements, installation, configuration, running, testing, systems integrations, user training, delivery and making necessary changes. During this phase, the proposed web application is implemented and tested. This reveals opportunities for physical design changes and reorganizing, an activity referred to as system tuning which continues as long as the database and applications are evolving besides performance problems is detected.

The front end of the system is designed using HTML, CSS and Java script. HTML is used to design the user interfaces of the proposed LIMS web based system. CSS is used to design the web pages of the proposed LIMS web based system. Java script is used to control the browser, and for validation of the system. PHP

is used as the backend scripting language of the system. It is specific language for web based system development. The proposed LIMS system is implemented using a Wamp server version 2.4 that includes Apache server version 2.4.4, MySQL version 5.6.12 and PHP version 5.4.12 besides Notepad++ 7.7.1 and adobe Photoshop. As indicated in figure (6) part of Wamp server PHP code for querying the system's statistics of tests done within a specified day.

```
<?php
include '..\dbconnect.php';
if(isset($_POST['todaytestings'])){
$da=date("Y-m-d");
//query testing details
$testqry = mysqli_query($dbhandle, "SELECT * FROM patients_testings where Date='$da' ")or die(mysqli_error($dbhandle));
//disply table headerss
echo"<div class='table-responsive'>
<table  class='table table-striped'>
<tr><th>Date</th>
<th>Ref No</th>
<th>Testings</th>
</tr>";
//displaying results
if(mysqli_num_rows($testqry)>0){

   while($rowqry = mysqli_fetch_assoc($testqry)){
      $mySring = $rowqry['testings'];
         $myArray = explode(',', $mySring);
      echo"<tr><td>".$rowqry['Date']."</td>";
      echo"<td>".$rowqry['ref_no']."</td>";
      for($i=0; $i<sizeof($myArray); $i++){
         $namequery = mysqli_query($dbhandle, "SELECT * FROM testings WHERE TestId='$myArray[$i]' ")or die(mysqli_error($dbhandle));
         while($rownamegry = mysqli_fetch_assoc($namequery)){
            echo"<td>".$rownamegry['TestName']."</td>";
         }
      }
   }
}
}
```

Figure 6. Part of PHP code for tests done with a specified day

The system is password-protected. Each user will be assigned system access privileges appropriate to its role. After a successful login in, which means that the user enters his credentials (username and password) correctly, the user accessed to the LIMS system home page as shown in figure (7). The administrator gives each user/physician the necessary credentials to log in to the system. In the upper right side, there are two notification signs; the first one indicates pending patients, which means those who have tests that still have some fields to be filled. In pending state, the test results are edited in case of wrong information entrance. The second sign indicates the completed tests results, which means those patients with completed tests (no fields are left blank). These tests are ready to be forwarded as reports to the patients after paying the total bill amount. In addition, the home page has a calendar to enter events or notifications. Clicking on any entered notification will let the user to read, edit or delete that notification.

Figure (8) and (9) indicate Add Patient and Manage Test pages, which include their personal information, besides display the lastly registered patients and the required test. Clicking on any of listed patient let the system user (physician) to edit that patient information.

When clicking on Manage Patients from the left side in the main navigation, patients are displayed according to the number specified in the Show entries. When selecting one of the patients, his/her personnel information is displayed with his/her bills that can be filtered using the fromDate and toDate textboxes. The system user (physician) can create a bill for the patient by clicking on the Bill button.

The system user (physician) creates a new bill. When specifying all the required tests and click the Submit button by doctor. In case system user (physician) enters the test result, it can be modified but the test itself can't be deleted. The bill will stay in the pending state until all tests results are completed and entered. At that point, the bill will be calculated and turned into the finished state. When all tests results are entered, a report is written and delivered handed to the patient after paying the remaining bill amount.

When the user selects the Doctor option. Here this user is added as a new doctor who send patients to the lab. A table indicates an easy access to the last entered doctors. To view/edit a specified doctor's information, it is possible form the displayed table. The patient's number

is sent by that doctor to the related Lab. The result can be filtered according to a specified date. When the user selects the Bio-Staff option from the left side bar, the system admin can add a new user and edit the information of the existing once. The admin can also disable a specific user account to prohibit him from accessing the system. After disabling that user, the admin can delete that account. When selecting Test option. The user can add a new lab, group and/or test. It can also edit/delete a specified test.

When selecting Statistics option. This page displays the earnings by day/week/month and the tests that are required at the current month. When selecting Purchases option. Here the user (physician) can add the items required in the lab work and their quantities.

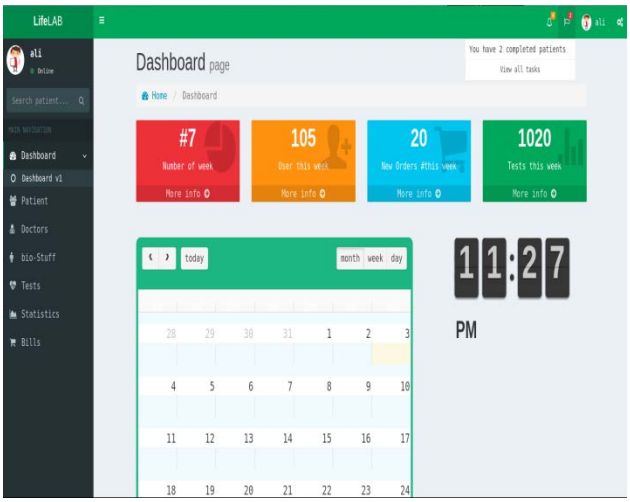

Figure 7 The Lab home page

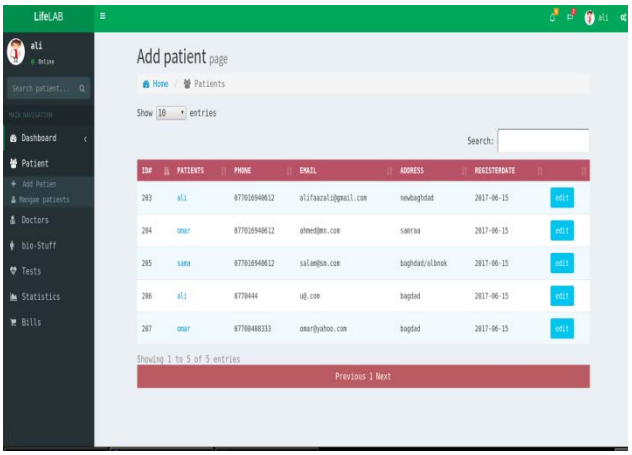

Figure 8 Adding Patient Page

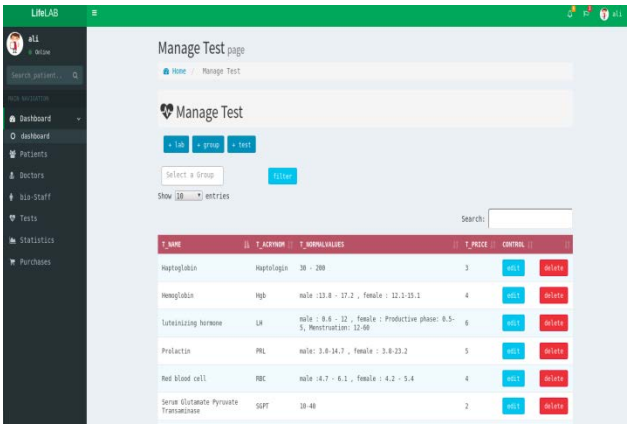

Figure 9. Managing Test Page

Insert tables after they are cited in the text. Tables are referred to in the text by “Table n” (capital T). Table heads should appear above the tables. When placing more than two tables under the same number of **title, assign subtitles** by dividing each table by (a) or (b). For example: Table 1, Table 2(a) and 2(b). Avoid any colors or shadings in the table.

5. Conclusions

People are relying increasingly on computer systems to support their daily activities. Therefore, the proposed LIMS provides a computerized way to manage a clinical/lab system in an efficient and accurate data-manipulation manner. The success of the system

is depending on the patients' satisfaction. As it is important whether the developed system is the best output for the requirements of the patients or it is not within the selected scope. The performance evaluation of the system from the perspectives of both developers and users was applied for both hardware and software. As each computer system can fail in two major ways. Firstly, a functional failure occurs when the system fails to perform the correct results for a given set of inputs. Secondly, a performance failure occurs when the system operates correctly but fails to deliver the expected results in a timely fashion. Therefore, in designing our proposed system we assured to guarantee that neither functional nor performance failure would occur. It is then necessary to predict the performance of computer systems when they are under design and development, as well as to predict the impact of changes in configurations of existing systems. This system was tested on fifteen persons, it meets many advantages over the previous systems. Such as handling reports easily besides its friendly user-friendly interfaces designed to optimize efficiency and maximize productivity. In software development, a typical initial reliability may range around 83%-87% [9]. As this system has approved initial reliability of 90%, it is acceptable and it is fulfilling many requirements of the end users in different ways such as:

- Tests reports can be viewed and downloaded online confidentially.
- Regular patients can register online and maintain their past tests reports with their cost estimation.
- Doctors can view their patients' tests reports online easily.

Therefore, this system can be used independently as a standalone system for a private clinical laboratory or as part of a full medical institution system. LIMS system provides three main characteristics:

1. Accuracy: to produce correct, precise and repeatable results
2. Efficiency: to help to computerize and speed up hard tasks
3. Management: to store and retrieve results quickly.

Few enhancements might be added to the proposed system to facilitate end users with some new features for them to be implemented as a mobile application in the future.

Conflict of interest

There are not conflicts to declare.

6. References

1. K.L.Viraj Prasanna, "Web Based Report & Invoice Generating System For Hope Diagnostics Medical Laboratory Service", B.Sc. thesis, University of Colombo School of Computing, 2018.
2. Zhao T, Stamelos EMS, Tsividakis G, Gurman J, Mitchell MJ, Klimstra DS, Reuter VE and Sirintrapun SJ, "An Enterprise Approach for Pathology Reporting Utilizing PDF Functionality for the Electronic Medical Record", Journal of Health & Medical Informatics, DOI: 10.4172/2157-7420.1000244, 2016.
3. Mariia Gaponova, "Analysis of ICT System in the Delivery Health Care Service", B.Sc. Thesis, Lapland University of Applied Science, 2017.
4. R. Elmasri and S. B. Navathe, "Fundamentals of Database Systems", Pearson, 7th edition, 2015.
5. S. A. Asabe, N. D. Oye and M. Goji, "Hospital Patient Database Management System", COMPUSOFT, An international journal of advanced computer technology, Volume-II, Issue-III, 2013.

6. J. L. Sepulveda and D. S. Young, “The Ideal Laboratory Information System”, Archives of Pathology & Laboratory Medicine: Vol. 137, No. 8, 2013.
7. Gregory A. Storch, “Automated real-time collection of pathogenspecific diagnostic data: Syndromic infectious disease epidemiology”, JMIR Public Health and Surveillance, Washington University School of Medicine in St. Louis, 2018.
8. Yang Yang, Atreyi Kankanhalli and Sarada Chandran, “A stage model of information technology in healthcare”, Health Technol, DOI 10.1007/s12553-015-0097-z, 2015.
9. Zinah Jaffar Mohammed Ameen, “Android Quiz Application based on Face Recognition”, Recent Advances in Computer Science and Communications, Bentham sciences, DOI: 10.2174/2213275912666190830155305, 2019.