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Implementación of a health system for the management of ambulatory medical care, in the Medical Department of the Polytechnic School of Chimborazo, Riobamba – Ecuador

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Summary

This paper describes the development and integration of a new health system for the Polytechnic School of Chimborazo (ESPOCH), this system presents a client server architecture with theintegration of JSON services. In the development of the system, several tools were used, such as: the Angular 6 framework, SQL server 2016 and Type script. The developed system integrates methods that allow the management of electronic medical records, reservation of medical appointments, patient visits,among others; in the same way the profiles that were defined in the system are: administrator, nurse, pharmacy, secretary and doctor. As a result, a medical system was obtained according to the current needs of the medical department and patients of the ESPOCH, in order to measure the effectiveness and degree of satisfaction of the system with the users of the same a null and alternative hypothesis was raised, by means of the statistical method of chi-square, the data obtained as a result of the evaluation of the system were analyzed using a degree of freedom equal to 6 and a margin of error of 1%, thus obtaining a critical value (Vc) equal to 12.59 and from thechi-square distribution matrix of (x^2) a value equal to 1.33 was obtained. With these values obtained, the null hypothesis raised in the study is accepted.

Key Words: health system, medical appointments, electronic medical record.

Thematic axis: e-Health

1. Introduction

Internet is the fabric of our lives at this time, it is not future, it is present [1], for this reason at present organizations are completely dependent on technology to carry out their objectives [2] due to the large amount of information required to process, in this aspect computer systems have been developed for the electronic processing of information [3], So it is very useful the integration of computer systems that help in these processes and therefore implies organizations saving time and money.

In the field of health, information is crucial to achieve the goal "Health for All", as it is a determining factor in the training of professionals and the care of the general population [4], Information and Communication Technologies (ICT) are already revolutionizing access to comprehensive care of good quality, overcoming many difficulties [5], for its part, the Pan American Health Organization (PAHO), with its Strategy and Plan of Action on eHealth, promotes improvement in patient care through technological tools and methodologies [6], in recent years, both governments and the various actors of health systems, researchers and civil society have shown a renewed interest in the promotion and application of health systems. eHealth to meet the needs of information and comprehensive care [7].

The Polytechnic School of Chimborazo located in the city of Riobamba – Ecuador through the Medical Department and the Directorate of Information and Communication Technologies (DTIC) intend to provide the polytechnic community with a better and renewed health care service using technological tools that allow the integration of an e-health system providing a quality service.

2. Background

In the medical department of the POLYTECHNIC SCHOOL OF CHIMBORAZO (ESPOCH) currently has a health system which was developed in 2005 using .NET technology and SOAP services, this system is hosted on a Windows server 2003, in this sense all collaborators of the medical department together with patients interact through the medical system, taking into account that the patients of the medical department are all employees, workers, students and teachers of the ESPOCH, the system houses information around 20,000 users who make reservations of medical appointments, patient care, medical records among others.

Due to the technology that was used for the development of the current system, the technology used in the architecture of the servers and the large amount of information processing, the system has certain failures, among which it can be identified:

- SOAP web services go down.
- The medical system becomes saturated.
- The web server crashes and does not respond to requests.

Other drawbacks identified is that the current system lacks vital functions that are needed during the process of medical care to the patient and generation of morbidity reports, in this aspect table 1 details the main needs identified:

Table 1: Needs and consequences of the current ESPOCH medical system

Need	**Consequence**
The current system does not allow the registration of vital signs.	Taking signs is noted on a piece of paper prior to medical consultation.
The current system shows a general morbidity report.	The reports do not specify whether the patient is an employee or professional and to which agency or faculty he or she belongs.

The system does not have a nursing profile.	Records of medication supply and cures are recorded in an agenda.
The current system does not allow prescription registration.	The doctor should write down the medication and indications in a physical prescription.
The current system does not have a pharmacy profile.	The person in charge of pharmacy must keep track of it in an Excel sheet.
The system presents a medical history in a general way.	It does not thoroughly detail the information you need to know about the patient such as: pathologies, allergies, others.
The system in the profile of the doctors allows you to book appointments with a maximum period of 5 days.	Regular monthly care cannot be provided to chronic patients.
The system allows permits to doctors by working hours i.e. in the morning or afternoon hours.	If a doctor requires an hour's absence, all shifts of the corresponding schedule (morning or afternoon) will be lost.

Given these situations raised in the Directorate of Information and Communication Technologies (DTIC) it was decided to develop and implement a new system, this system must contemplate the modules that cover the current needs of the medical department, it must also be developed using current technology and that allows it to be scalable over time with the objective that supports the processing of all the information required in the medical department.

The main objective of this work was to develop and implement a new medical system making use of current technology

3. Materials and methods

3.1. Studio area

This work was elaborated in the development area of the Directorate of Information and Communication Technologies belonging to ESPOCH which is a higher education institution in the city of Riobamba, Ecuador

3.2. Research method

For the development and implementation of a new medical system in the ESPOCH, the hypothetical-deductive method was used, which allows to observe specific cases that lead to the formulation of hypotheses, then the implications are passed on deductively [8]. The interview was used as a tool, which is a very useful technique in qualitative research to collect data [9].

In this area, meetings were held with the director of the medical department who is the person who knows the needs of implementing a new system that meets the expectations of doctors and patients, once the requirements of the new system were obtained and in order to measure the efficiency of the new system to be developed, a null hypothesis (H0) and an alternative hypothesis (H1) were formulated, which are described below:

H0: The development and implementation of a new medical system will improve patient care processes.

H1: The development and implementation of a

new medical system will not improve patient care processes.

4. Development of the Medical System

4.1. Electronic health system or e-health

Prior to the development of the medical system, the guidelines of an e-health system must be taken into account, which are basic instruments that seek to achieve a more efficient, effective and transparent health system [10], in this sense the use of ICT in the health sector is increasingly important in the face of the epidemiological challenges posed by the transition and growth of demographic data [11]. On the other hand, the potential of the Internet, mobile communications, portable devices and electronic instrumentation in the development of e-Health services is evident [12].

"e-Health" should not be considered only as the consequence of the use of some ICTs in health care, but as "different ways of delivering health services, in many cases more efficiently and effectively, and in others in a more efficient way [13].

In this sense, ESPOCH seeks to implement a new electronic health system or e-health which improves medical care processes and includes necessary modules that the current system lacks.

4.2. System users

After an analysis of the requirements presented in the medical department, the profiles of the users of the system were identified based on the activities carried out by each one, in table 2 the users and their functions in the system are described.

Table 2: User roles.

Role	Activities in the system
Manager	It is the user who is responsible for the administration of the system, has as main functions the registration of doctors, registration of hours of attention, scheduling of medical appointments, among others. This role was assigned to the director of the medical system.
Doctor	This user is responsible for patient care among the main functions is the creation of medical history, record of medical consultations, assignment of medication, among others. This role was assigned to ESPOCH physicians who belong to the medical department.
Nurse	This user is responsible for making a quick check to the patient prior to medical care, among the main functions has the taking and recording of vital signs, perform cures, supply of medication, others. This role was assigned to the nurse of the medical department.
Secretary	This user is responsible for carrying out administrative procedures of the medical department, can also schedule medical appointments and records patient data for this reason has its role in the medical system.
Pharmacy	This user is responsible for delivering the medication to the users their activities in the system is to verify the medication sent by the doctor and generate reports of the stock of the existing medicine in

	stock.
Patient	This user is the one who is made to attend in the medical department his activities in the medical system is: schedule medical appointments, view the medical consultations registered by the doctor, visualize the medication and instructions assigned in each medical consultation.

4. 3. Materials and methods

In a first approach in the medical department was to listen and analyze the current needs of implementing a new medical system that is functional 24 hours a day, so it was decided to establish a work environment that is adaptable and scalable over time, in this way it was decided to integrate the use and management of REST services (Representational State Transfer) and as a development tool Angular 6 was used, Table 3 details the tools used in the development of the medical system.

Table 3: Tools used for system development.

Tool	**Construction characteristics**
SQL Server 2016 Database Engine	SQL was used as a database engine because it is a query language that contains many other capabilities besides querying databases [14].
Angular 6.	It is an Open Source JavaScript framework developed by Google, used to create Webapps in client language with JavaScript running with the well-known single-page applications that extends the traditional HTML with its own tags [15].
Windows server 2016.	Windows Server supports an enterprise-grade virtualized server computing environment for creating and managing virtual machines [16].
Internet information Services 10 (IIS10).	IIS 10 is not the revolutionary change in architecture, however, it offers new functionality, as well as introducing administrators to new security, scalability, and administrative features [17].
Postman.	It is a tool that allows you to perform tests on REST services. However, this tool does not allow automated test development or integration into continuous integration servers [18].
HTML 5	It is a collection of standards for the design and development of web pages. This collection represents how information is presented in the Internet browser and how you interact with it [15].
CSS style sheets	CSS is a stylesheet language created to control the appearance or presentation of electronic documents defined with HTML and XHTML. CSS is the best way to separate content and presentation and is essential for creating complex web pages [19].

Type script	TypeScript is a modern programming language that allows you to create robust web applications in JavaScript, it does not require any type of plugin [20].
Bootstrap	It is a framework for web application development, it is a simple and lightweight tool that includes a CSS file and a JavaScript [21].
Node JS	It is a framework that uses a non-blocking, event-oriented model, which makes it lightweight and efficient, one of its qualities is its native ability to work with websockets, it is the most popular web platform for real-time applications [22].

4. 4. System architecture

The system is designed under the client-server architecture that is a distributed application model in which the tasks are distributed between the providers of resources or services, called servers, and the demanders, called clients [23], in addition the system is developed based on the consumption of services, in this case JSON services will be used, which is the method with the highest performance when serializing and deserializing objects [24].

Under this architecture the back-end and front-end of the system was defined, for programming it was done in Angular 6 that presents a structure model view controller (MVC), this structure forces in an orthodox way to have the code ordered, making use of controllers to send data to the view, models for database, directives, services or filters, for dependency injection [25].

In the front-end the entire visual part of the system is defined, that is, the user interface in this section the Bootstrap web design framework was used, which defines a web template the same that was editing the HTML and CSS code to fit our system, thus obtaining an interface according to the standards established by ESPOCH.

In the back-end part, the JSON services that feed the front-end or view were created, these implemented services allow interaction with the database that was implemented in SQL server 2016, using Angular 6 the connection to the database was created to later create the SQL statements and these results are exposed in JSON format.

Because the services were developed in Angular 6 Node JS was used, which is part of this framework, it comes with several useful modules, so there is no need to write everything from scratch, such as, for example, defining data type to the variables used [26], figure 1 describes the proposed architecture of the system.

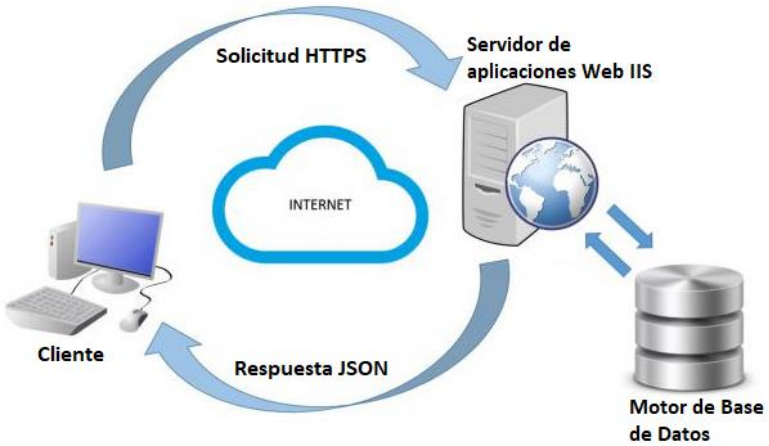

Fig. 1. Architecture of the medical system.

It should be considered that the patients of the medical center are the students and employees of the ESPOCH therefore this system is linked to the academic system and the human talent system correspondingly, in addition the health system must house information so it has its own database, for which the SQL server 2016 database engine was used.

In order to maintain the integrity of the patient data that is registered in the medical system, when the electronic medical record is created, the medical system is linked to the civil registry services in order to obtain the true data of the patient, to achieve the integration of the other systems with the medical system in the back-end a module was created where the consumption of the services of these external systems.

In this environment the medical system makes a GET request to the other systems involved and these systems return a response in JSON format, figure 2 explains the link of the medical system with other systems.

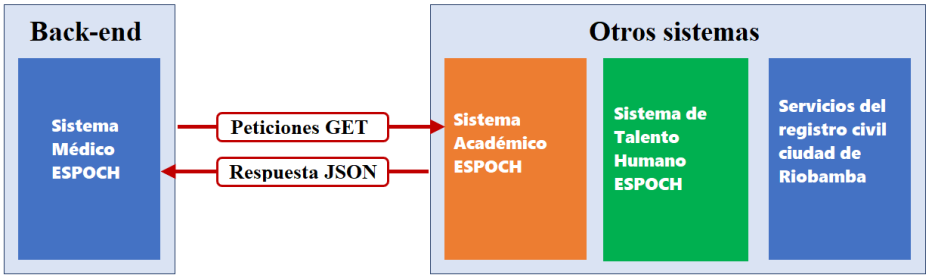

Fig. 2. Integration of the medical system with other systems.

5. Implementation of the Medical System

5.1.Deploying System JSON Web Services

In the production environment of the services developed for the medical system, a Windows Server 2016 server was configured for JSON services where all the necessary services were deployed that communicate to the medical system's own database and also interacts with other systems that intervene in the doctor, in this sense in the server the IIS was configured so that it can process Node JS, later a website was created with the name of "services" and the same was assigned a public address and DNS under the name of ESPOCH, in figure 3 shows the structure of the server where the services are hosted.

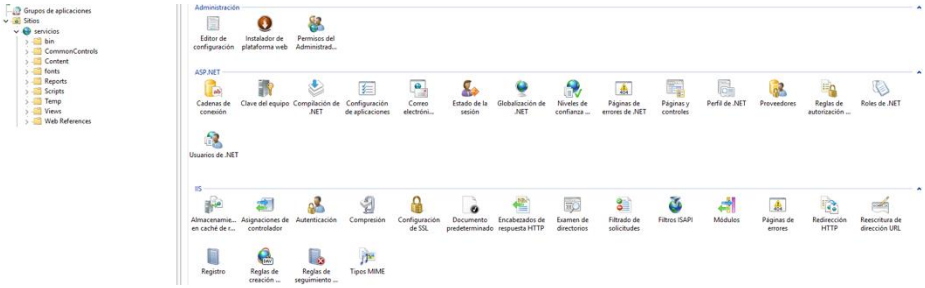

Fig. 3. Deploying JSON services on the server

5.2. Deployment of the medical system

For the deployment of the medical system in production, in the same way, a Windows server 2016 server was configured for web applications,

where Node JS was configured so that it can be executed in the IIS, later the website was created within the server to the same that assigned the name of "doctor" and a DNS under the name of the ESPOCH.

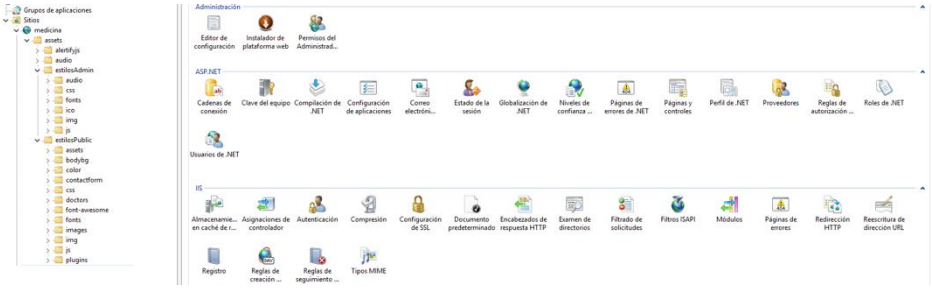

Fig. 4. Deployment of the medical system.

With this structure implemented in the deployment of the medical system it was possible to separate the back-end from the front-end having the services of the view separately, it should be noted that from the view the user can make requests to the different databases as the case may be, in this aspect the back-end serves as an intermediary between the medical system and the databases, for this reason in the structure of the view a configuration file was defined that contains the URLs of the services provided by the JSON service server.

A controller was also created in the view which invokes the configuration file to obtain the addresses of the services in the form of a variable, the objective of implementing a controller is to invoke the services in a more specific way that is, it is called by the name of the service function and if necessary receives parameters by GET or POST, Figure 5 shows the consumption from the view of web services from different sources or databases.

```
import { Injectable } from '@angular/core';
import { Http } from '@angular/http';
import { map } from "rxjs/operators";
import { recursosMedico } from "../recursos/interfaz";

@Injectable()
export class PublicoService {

  constructor(private http: Http, private rutas: recursosMedico) {
  }
  horarrioAtencion() {
    return this.http.get(this.rutas.rutasPublico + "/getHorariosAtencion").pipe(map(res => res.json()))
  }
  verEscuelaCarera(carrera) {
    return this.http.get(this.rutas.rutasMaster + "/getEscuelaCarrera/"+carrera).pipe(map(res => res.json()))
  }
  personaCentralCedula(usuario) {
    return this.http.get(this.rutas.rutasCentralPersona + "/personaPorDocumento/" + usuario).pipe(map(res => res.json()))
  }
```

Fig. 5. Consuming services from the system view

6. Results

6.1.Medical system integration

This section describes the developed medical system and some of its functionalities, Figure 6 shows the main screen of the medical system.

Fig. 6. Medical System Home Page

To enter the medical system, it was done through the institutional mail of the ESPOCH so that only people who are linked to the institution have access to it.

Fig. 7. Login to the medical system

Next, figure 8 shows the main screen of the administrator user in which you can see the functions you can perform and a list of appointments reserved for the current date.

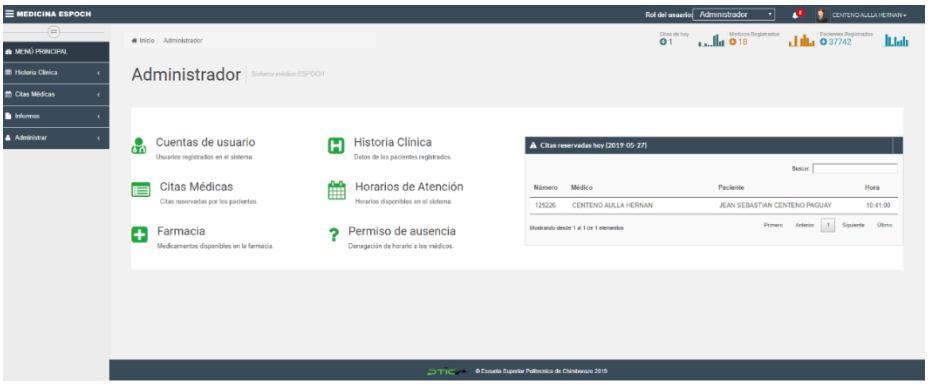

Fig. 8. Medical system main screen

6.2. Analysis of results

Once a new medical system has been developed and implemented, a study of the impact of this system on the medical department is carried out, therefore, the level of satisfaction and acceptance of doctors is measured.

6.2.1.Statement of the hypothesis and variables

In order to measure the level of satisfaction and acceptance of the new medical system implemented, two hypotheses were proposed (null and alternate) which tells us that:

H0: The development and implementation of a new medical system will improve patient care processes.

H1: The development and implementation of a new medical system will not improve patient care processes.

Based on these hypotheses, a dependent variable and an independent variable were defined as follows:

Dependent variable: The development and implementation of a new medical system.

Independent variable: it will improve patient care processes.

6.2.2.Population and assessment criteria

The study universe was defined as the 9 people who work within the medical department of ESPOCH. In order for the sample to be representative, it is equal to the study universe, Figure 9 gives a general detail of the medical department staff.

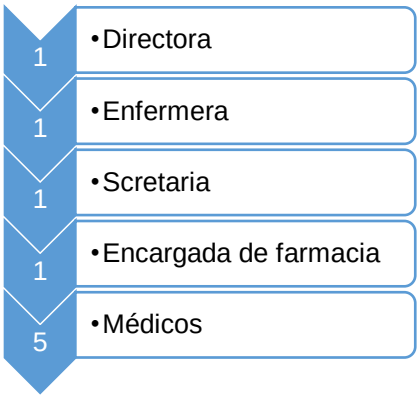

Fig. 9. Medical Department Staff

In order to obtain information that allows evaluating the defined hypothesis, the dependent variable of this hypothesis, the technique and source of obtaining information as shown in Table 4 are proposed.

Table 4. Definition of the dependent variable, indicators, techniques and sources of information.

Variable	Indicator	Technique	Fountain
Improve healthcare processes	Vital signs recording	Survey	Medical Department
	Morbidity reports	Survey	Medical Department
	Prescription Record	Survey	Medical Department
	Medication Control	Survey	Medical Department

The technique of obtaining information is the survey so a small questionnaire consisting of 4 questions was carried out with which it is intended to make an analysis of the impact that the new system has with the staff of the medical department, table 5 shows the results obtained.

Table 5. Result of the questions posed for the evaluation of the system.

No.	Evaluation Questions	Low	Middle	High
1	Does the system show you morbidity reports?	0	3	6
2	Does the system allow you to keep track of chronic patients?	0	4	5
3	Does the system present a medical record with all the necessary information?	0	4	5
4	What is a degree of satisfaction with the use of the system?	0	2	7
	Total	0	13	23

6.2.3.Chi-square

With those obtained as a product of the questionnaire proceeds to make an analysis of the hypothesis for which the statistical method of chi-square was implemented, this test deals with the sum of the squares of the differences between the expected frequencies (fe) and the observed frequencies (fo) with respect to the expected frequencies (fe) [27], in the following formula the chi-square distribution is expressed.

$$x^2 = \sum \frac{(fo - fe)^2}{fe} \qquad (1)$$

To accept the null hypothesis the critical value must be greater than the chi-square value, otherwise the alternate hypothesis is accepted.

6.2.4.Degree of freedom and level of significance

The degrees of freedom of chi-squared depend on the number of parameters that need to be found to

obtain the expected frequencies [28], the following formula is used to calculate the degree of freedom.

$$gl = (f - 1)(c - 1) \quad (2)$$

Using the formula the following result is obtained:

gl = (3-1) (4-1) **gl** = 6

The level of significance that is established in social sciences and psychology is normally 0.05, this can vary in the decision rule to 0.01 and 0.001 if greater certainty is required in the hypothesis test [29], in this study a significance level of 1% was used with a probability of 99% for the null hypothesis to be accepted.

6.2.5.Proof of the hypothesis

To prove the hypothesis the first step is to determine the values of the expected frequency (fe) and the values of the observed frequency (fo) these values are shown in tables 6 and 7.

Table 6. Frecuencia observed

Low	Middle	High
0	3	6
0	4	5
0	4	5
0	2	7

Table 7. Expected Frequency

Low	Middle	High
0	3,25	5,75
0	3,25	5,75
0	3,25	5,75
0	3,25	5,75

With the values of the observed frequency and expected frequency, the calculation of the chi-square contingency matrix is made, for which formula (1) is used, the contingency matrix is expressed in Table 8.

Table 8. Chi-square matrix

fo	fe	(fo – fe)2 / fe
3	3,25	0,019
4	3,25	0,173

4	3,25	0,173
2	3,25	0,480
6	5,75	0,010
5	5,75	0,097
5	5,75	0,097
7	5,75	0,271
Total		1,324

Once the critical value is obtained, the chi-square value is determined, for which it must be located in the chi-square distribution table considering that the degree of freedom is equal to 6 and the margin of error is equal to 0.05.

DISTRIBUCION DE χ^2

Grados de libertad	Probabilidad										
	0,95	0,90	0,80	0,70	0,50	0,30	0,20	0,10	0,05	0,01	0,001
1	0,004	0,02	0,06	0,15	0,46	1,07	1,64	2,71	3,84	6,64	10,83
2	0,10	0,21	0,45	0,71	1,39	2,41	3,22	4,60	5,99	9,21	13,82
3	0,35	0,58	1,01	1,42	2,37	3,66	4,64	6,25	7,82	11,34	16,27
4	0,71	1,06	1,65	2,20	3,36	4,88	5,99	7,78	9,49	13,28	18,47
5	1,14	1,61	2,34	3,00	4,35	6,06	7,29	9,24	11,07	15,09	20,52
6	1,63	2,20	3,07	3,83	5,35	7,23	8,56	10,64	12,59	16,81	22,46
7	2,17	2,83	3,82	4,67	6,35	8,38	9,80	12,02	14,07	18,48	24,32
8	2,73	3,49	4,59	5.53	7,34	9,52	11,03	13,36	15,51	20,09	26,12
9	3,32	4,17	5,38	6,39	8,34	10,66	12,24	14,68	16,92	21,67	27,88
10	3,94	4,86	6,18	7,27	9,34	11,78	13,44	15,99	18,31	23,21	29,59
	No significativo								Significativo		

Fig. 10. Chi-square distribution table

In this study a degree of libertas equal to 6 was calculated and with a margin of error of 1%, under these values in the chi-square distribution table a value of (x^2) equal to 1.33 and the critical value (VC) is equal to 12.59 is obtained. As the critical value is greater than the chi-square value, the null hypothesis that says "The development and implementation of a new medical system will improve patient care processes" is accepted.

7. Discussion

The medical system was developed and implemented based on the needs of the personnel working in the medical department of ESPOCH, in this sense the objectives set for the system were met.

It should be noted that prior to the development and implementation of the developed system the medical department has a health system which was implemented in 2005, with the passage of time in the medical department new needs arose the same that did not contemplate the previous system. As a solution, a new system was integrated, which presents a new structure and integrates new modules and user profiles that the previous system does not have.

Section 2 of this document describes the most relevant needs presented by the previous system of medicine, table 9 below describes how the current system solves those needs.

Table 9. Solution presented to the needs of the previous system.

Shortcomings of the previous system	**Solution implemented**
The above system does not allow the recording of vital signs.	In the current system you can assign vital signs to the electronic medical appointment, so that at the time of the consultation the doctor will be able to see the vital signs in the patient's profile.
The above system shows a general morbidity report.	The current system shows a detailed morbidity report in which you can see the reason for the consultation, age, sex, the faculty to which you belong in the case of being a student, in the case of being employed the dependency where you work is displayed.
The previous system does not present a nursing profile.	The current system presents a nursing profile where nurses can schedule medical appointments, record cures, and record medication supplies to patients.
The above system does not allow prescription registration.	In the current system, the doctor can assign a medical prescription and the indications that correspond to each consultation.
The above system does not present a pharmacy profile.	The current system includes a pharmacy profile where the person in charge of pharmacy can see the prescriptions issued by doctors.
The above system presents a clinical history in a general way.	The current system presents a complete electronic medical record in which information such as pathologies, among others, is included.
The previous system in the profile of doctors allows you to book appointments with a maximum period of 5 days.	In the current system, doctors do not have a deadline for registering medical appointments, which allows them to follow up on a monthly basis for chronic patients.
The previous system allows permits to doctors by working hours i.e. in the morning or afternoon schedule.	In the current system, the administrator can assign permissions to doctors on an hourly basis based on working hours.

Another advantage of the current system is that it is linked to the civil registry of the city of Riobamba in this way true information is obtained from the patients who register the system, in the previous system the person in charge of registering patients had to write all the information that belongs to that patient so the system presented inconsistency in the names of the patients.

8. Conclusions

Of the present made that presents the following conclusions:

It was possible to develop and implement a medical system which arises from the needs

that presents the health system implemented previously, in this virtue the new system includes modules that solve the needs raised, among the solution alternatives implemented is the integration of new user profiles, the consumption of services of the civil registry of the city of Riobamba.

The current system implemented presents a new structure which is based on the client-server model, on the server side you have the publication of web services in JSON format and on the client side you use the Controller View Model architecture being the controller who makes the consumption of the services and later the data are exposed in the view.

For the evaluation of the efficiency and degree of conformity with the implemented system, the chi-square statistical method was used, for which we worked with the common error methodthat isl 1% and a degree of freedom equal to 6. From the chi-square contingency matrix a critical value equal to 12.59 was obtained and from the chi-square distribution matrix a chi-square value equal to 1.33 was obtained. With these values obtained it can be seen that the null hypothesis raised in the study is accepted.

Thanks

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