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Presentation

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Article

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Implementation of the CMMI-DEV N3 model in an educational institution: perspective from software quality

ALCÁNTAR-ORTIZ, Patricia*†, MARTÍNEZ-LÓPEZ, Fernando José and VEGA-OLVERA, Gustavo Iván

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Abstract

Quality has become crucial for small size and medium size companies, due to increasing demand for quality by software users. Therefore, it is essential to work under standars that are leading us to optimal results. This is a mather of concern for the Software Develepment Center (CDS) at the Instituto Tecnologico Superior del Sur de Guanajuato (ITSUR). In 2009, this concern was ddressed with the Capability Maturity Model Integration (CMMI) level 2, achieving certification in 2010. Despite the benefits of level 2, the CDS faced daily burdensome and bureaucratic processes; as a result, in 2012 the decision was made to carry out an improvement project with the objective of achieving certification in level 3 version 1.3, in model CMMI, which it was sold as a less heavy version and whith a greater adptability o the company. The implementation involved full time teachers and students, successfully achieving their certification and aboye all mitigating the deficiencies.

Quality, CMMI, Software, Standars

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Introdution

The implementation of quality models is one of the most latent challenges at present within small and medium-sized enterprises (SMEs). This paper reports the implementation of CMMI in the constellation Development (DEV) at its level of maturity 3, and in its version 1.3, in the CDS. CMMI is a model of international quality that emerged in the United States and that for years has begun to interfere in different countries, not being Mexico the exception, one of the challenges with CMMI is the attachment to practices that have not been permeated by the Mexican culture, however in its 1.3 version leaves aside its rigor and allows a better attachment to the way of working of each company, this without leaving aside the use of good practices.

Problem

The quality of the software is a concern that is shared among the members of the CDS. This concern lies in delivering software products on time, meeting the expected costs of meeting customer expectations. In response to this concern, in 2010 the CDS was certified in the CMMI-DEV N2 model, thanks to the implementation of the model, the CDS was able to guarantee the planning and execution of its processes according to the previously established policies, an involvement of all the interested parties, which is monitored, controlled and evaluated. However, despite the kindness shown by the model in its level 2, the CDS faced the following problems:

- Some of the engineering processes are not carried out and those that are implemented are incomplete.
- Estimation of costs and inaccurate times.
- Processes not focused on continuous improvement.
- Long processes, with excessive detail and bureaucratic.
- Work on projects with the same life cycle, despite their differences in size and complexity.

Objectives

General objective

Implement processes of maturity level 3 of the CMMI-DEV model, in its version 1.3, in the CDS of the ITSUR.

Specific objectives

- Make a diagnosis.
- Define an improvement project.
- Define and adjust the processes, incorporating the best practices of the CMMI-DEV.
- Verify the implementation of the processes.
- Perform implementation cycles.
- Perform a pre-evaluation.
- Conduct the formal evaluation.

Theoretical framework

The role of quality in software development companies

Currently, you can not visualize a successful company that is not contemplating quality activities in its processes. The quality from the point of view of the software, are all those activities that are carried out to ensure the satisfaction of the client and end users in each of the products, considering among them manuals, minutes, specification documents of requirements and the same software.

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It is unacceptable that companies currently deliver products of poor quality and after their delivery they want to remedy the incidents (Sommerville, 2002).

Process improvement

The improvement of processes in the software is a mechanism of continuous improvement of quality, which basically consists of consistently applying those practices that provide good results and eliminating or changing those practices that cause problems or give bad results.

The authors (Pattini, Calvo-Manzano, Cervera, & Fernández, 2004) mention three fundamental aspects in process improvement:

– Choose the improvement model that best suits the institution.

– The model must have four stages: commitment to improvement, diagonistic of the company, planning of the improvement model and implementation of the planning.

– Select a process model that serves as a reference.

– Finally, selection of the method that will be used in the evaluation stage.

The dilemma of software quality

When a company invests a lot of effort in perfecting its processes so that these result in "good" software, some complications occur, in the attempt they realize that they have invested so much that now their software is out of reach of many of their clients and they enter In a dilemma, how much effort should I invest in quality activities? This has been the starting point of some of the current software methodologies where they seek a balance, to be able to generate acceptable quality products that do not require much effort.

Process model: CMMI

CMMI for development or CMMI-DEV is a reference model that covers the activities to develop both products and services. Organizations from numerous sectors, including aerospace, banking, hardware, software, defense and telecommunications, use the CMMI-DEV model (Chrisssis, Konrad, & Shrum, 2010). This model helps solve common problems in companies, such as products and services that do not meet customer requirements, delays in delivery and low profitability in projects, high operational costs, low productivity, low levels of innovation and demotivation of staff , all of which results in strategic vulnerability and little competitiveness in the market, one of the fundamental principles in the adaptation of the CMMI model in organizations is the commitment of the high hierarchical levels, these should make possible the entire implementation process (Arboleda , Paz, & Cassallas, 2013).

Methodology

In the present topic, the process that was carried out within the CDS for the implementation of the CMMI-DEV model is described. As a first step was the selection of the consulting company, after having carried out the appropriate negotiations the improvement project was started, which was divided into 5 phases:

First phase: Diagnosis and improvement planning

A comparison was made of the current processes of the CDS and the CMMI model, was carried out by the company Avantare and as a result a diagnosis was obtained, which was crucial for the development of the improvement project plan, the most outstanding findings are shown in Table 1.

Strengths	Weaknesses
Attachment by 55% at level 2	Lack of organizational metrics
Consolidated work team	Attachment by 8% to level 3
There is an estimation tool	The generic practices of the model are not fully met
Handling software tests	

Table1 Fortalezas y debilidades identificadas.

Source: CDS database

Once the diagnosis was finalized, the improvement plan was carried out, which was based mainly on implementing the actions that would help to strengthen the weaknesses found. In addition to assigning responsibilities to each of those involved.

Second phase: definition and adjustment of processes

This phase and the rest of the phases represent the implementation of the improvement plan. During this phase the following activities were carried out:

- Standardization of work products.
- Definition of organizational objectives.
- Definition of the organizational structure.
- Definition of policies
- Definition of the order of the process areas to be implemented. The order was as follows:
  - Administrative processes
  - Engineering processes
  - Support processes
  - Organizational processes
- Selection of pilot projects. Three projects were selected, two of which were internal and one external.
- Description of the processes and generation of work products.

Third phase: verification of the implementation of the processes

An analysis was made of the current status of the pilot projects and the phase in which they were in order to establish what processes would be implemented in them. Two implementation cycles were carried out:

First cycle: the main activities were to implement the work processes and products, in the pilot projects and identify improvements and / or changes. In Table 2, some of the identified improvements are shown.

Improvement	Impact
Generate a metric that shows the effort in correcting anamolias	High
Standardize the use of Enterprise Architect	Medium
Perform control variables for PPQA review criteria	Medium

Table 2 Concentration of improvements

Source: CDS database

Second cycle: it consisted of executing the same processes and products of the first cycle, including the improvements.

Fourth phase: pre-evaluation

The company Avantare was responsible for directing the evaluation method. He was in charge of evaluating the evidence generated by the CDS in the application of the CMMI model. The objective was the physical evaluation of the evidence of the implementation of the CMMI model and also to ensure that the members of the CDS have correctly implemented the model.

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Fifth phase: formal evaluation

In the last phase the Avantare company carried out the formal audit, with a team of 6 people (4 external auditors, 2 internal auditors and a leading auditor) called by the CMMI model as SCAMPI A, the only method that can grant a level of maturity.

Results

The implementation and certification in the model, was achieved in a span of 13 months, with 7docentes and with approximately 15 students of engineering careers in computer systems and information technology. From the implementation, various processes and work products were obtained, without which it would not have been possible to implement the model.

In table 3. It shows a comparison of levels 2 and 3, in hours per phase of the projects.

	N2	**N3**
Start	32.33 hours	29.44 hours
Analysis	209.98 hours	140.24 hours
Planning	41.4 hours	43.35 hours
Design	82.74 hours	54.53 hours
Coding	434.40 hours	370.86 hours.
Implementation	140.27 hours	206.86 hours
Closing	20.29 hours	11.09 hours
Total	961.41	856.37

Table 3 Time comparison

Source: CDS database

Before the certification in level 3 of the CMMI model, the CDS had heavy and bureaucratic processes, without leaving aside the lack of engineering processes, now with certification, the processes are more agile and simple, the treatment has improved and the approach with the clients and also it has been managed to improve the delivery time of the products (according to table 3 the time has been reduced by approximately 10%).

Therefore, it can be determined that the quality of the products and processes has improved.

Conclusions

The present work shows that the implementation of the CMMI-DEV model can be implemented in small companies, but also in an environment that combines academic work with the development of software projects. CMMI is a very complete model with large contributions for small companies, however, it is very heavy due to the large number of process areas it handles, it takes many hours of work to fully meet its objectives.

The success lies in finding a balance point and generating quality products that satisfy the customer but have not required much effort. The CMMI-DEV model, no doubt indicates what actions should be performed to generate quality software, finding the point of balance is part of the work of each of the organizations. Those that achieve it will have a huge competitive advantage over others.

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Automatic QR credentialing system applied to the "Ignacio Manuel Altamirano" Multiple Care Center

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Abstract

The present work designs and implements an automated system of credentialing using QR code, applying the agile methodology of software development called SCRUM. The QR will contain a useful information file, solving the need for students with multiple disabilities at the 48th "Ignacio Manuel Altamirano" multiple attendance center, to have a credential with meaningful information that allows them to receive better care in different situations, Highlighting situations of medical emergencies and security. Innovative software tools such as the Java programming language, Itext library for PDF management, Media Framework library for webcam management, database manager (MySQL), use of GPS and a QR code creation algorithm will be implemented, In order to obtain a credential and badge under the ISO / IEC-7810 standard on the properties of the quality of identification cards.

Credentials, QR Code, GPS, Students

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Introduction

The credentials that the students carry are a problem if they do not have it and do not contain the necessary information that identifies them or supports the condition that they are persons with disabilities. In order to innovate the process of the credentials, the software cascade method was used, which orders the stages of the process for software development, as well as the use of the QR Code and Java programming language, Itext library for PDF management, Media Framework library for webcam management, database manager (MySQL) and use of GPS, in order to obtain a credential and automated badge with your photo and substantial student information.

Justification

The present work will be done to contribute to the improvement of the process of generating credentials, making it easier and more useful to help the staff of the institution, parents and 80 students with disabilities that on average attend the Center of Attention Multiple No. 48 "Ignacio Manuel Altamirano" at different times, offering identification documents with emerging information technologies applied, which will allow them to have better attention in different situations, but especially in emergency situations that may arise.

It is important to implement the technological tools available to the institution, making the most of its benefits, optimizing the use of resources in order to minimize the considerable waste of office resources that currently happens in the institution.

Encourage applied research aimed at the development and implementation of free software that really benefits the society in which we live, applying new technologies in current issues that supports the line of generation and application of knowledge called "Emerging Technologies of Information and Communication" Stimulating the implementation of projects for the benefit of the community.

Problem

At present, the multiple care center "Ignacio Manuel Altamirano" n ° 48, with key 12dml0048d, has two types of credentials, one of them is provided by the government of the warrior state, which has personal data that identify the type of disability And name, the other is generated by the same school through a complicated and inflexible process, printing the front and back in different documents and then joining them, generating a reduction of office resources, as well as having the parents place the picture of the Student in the credential, for which the cost is increased with the transfer and acquisition of the photograph.

The information contained in these documents is not sufficient to identify and provide better care to students in various situations, such as the case of an emergency of various types, such as lost or a medical emergency. Another drawback is that the credentials of the government of the warrior state usually do not arrive in time and form, so that the students must go to the corresponding government facilities causing a complicated transfer due to the disabilities of these, consequently not all Students acquire with this document.

Hypothesis

Through the implementation of QR code you will get an automated credentialing system.

Objectives

General Objective

Design, develop and implement an automated system of credentialing using QR code to grant innovative identification documents with QR and GPS technology to the students of the multiple care center No. 48 Ignacio Manuel Altamirano.

Specific objectives

- Design and develop a database to store student information.
- Investigate and implement QR code to display information electronically.
- Design and develop the system using a Java programming language.
- Investigate and implement the use of GPS to locate the place of residence and institutions of the student's credential.
- Capture and implement photography to optimize the webcam credentialing process.

Theoretical Framework

QR code

A QR code is a two-dimensional matrix formed by a series of black squares on a white background. This matrix is read by a specific reader (QR Reader) in our mobile device and immediately takes us to an application on the Internet.

The term "QR" comes from "Quick Response" because of the immediate response they offer through their reading. Although the authors have patented their discovery, in order to encourage their acceptance and use, this Japanese company has decided not to exercise such patent rights and make public its specifications, which have become standardized documents in ISO, available to any person or organization. That its use is, nowadays, free. In addition, there are available to users multiple free applications that allow them to be read quickly and easily, and the link to the resource that links the QR code.

They are composed of three squares at the corners that allow the reader to detect the position of the QR code and a series of scattered squares that encode alignment and synchronization.

The QR code is fully adapted to the project since it is capable of storing a large amount of information in a small space such as a credential, it is important because identifying a person with different abilities is necessary to know all the data necessary for their rapid identification (Javier, Izquierdo & Cháfer, 2014)

Types of QR codes

QR code. Model 1 and model 2

Model 1 is the original QR code. The largest version of this code is 14 (73 x 73 modules), which is capable of storing up to 1,167 numbers. Model 2 is an upgrade in model 1, with the larger version 40 (177 x 177 modules), which is capable of storing up to 7,089 numbers. nowadays, the term QR Code generally refers to this type.

QR Micro Code

You only need an orientation detection pattern for this code, which allows you to print it in a smaller space than before.

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This code can be viable even if the width of its margin is 2 module-value (QR code requires a margin of 4 modulus of value at least around it). The largest version of this code is M4 (17 x 17 modules), which can store up to 35 numbers.

IQR Code

Code that can be generated with square or rectangular modules. It can be printed as a return code, a black and white reversal code or a dot pattern code (direct part mark). The maximum version can theoretically be 61 (422 x 422 modules), which can store around 40,000 numbers

SQRC

QR code that has a read restriction function. It can be used to store private information or to manage the internal information of a company). its appearance is not different from the regular QR code.

Frame QR

FrameQR is a QR code with a "canvas area" that can be used flexibly. Since letters and images can be inserted within the area of the canvas, FrameQR can be used for promotion, judgment of authenticity, and other various uses. (Qrcode 2017)

Standardization of QR codes

The process of standardization of QR codes has been the following:

October 1997: approved as AIMI (Automatic Identification Manufacturers International) standard: ISS-QR Code. Defines the codes "QR Code Model 1".

March 1998: approved as JEIDA (Japanese Electronic Industry Development Association) standard: JEIDA-55.

January 1999: approved as JIS (Japanese Industrial Standards) standard: JIS X 0510.

June 2000: Approved as International Standard for International Electrotechnical Commission (ISO / IEC): ISO / IEC 18004: 2000. Defines the codes "QR Code Model 2".

November 2004: added the "Micro QR" variant to the standard.

September 2006: update to ISO / IEC 18004: 2006. Defines the codes "QR Code 2005".

December 2011: Approved by GS1, an international standardization organization, as standard for mobile phones (Qrcode, 2017)

The standard specifies the characteristics of the symbology; Data encoding methods; Symbol formats; Dimensional characteristics; Methods of error correction; The reference algorithms for decoding; The quality requirements of the process; The application parameters eligible by the user; And a list of informative annexes (Javier Luque, 2017)

Java

It is an object-oriented programming language and a computer platform commercialized for the first time in 1995 by Sun Microsystems. Its main objective is that the applications are multiplatform, that is to say, that the application developers write the program once and run it on any device.

It has become one of the most popular programming languages in use. Currently, it belongs to Oracle Corporation. (Oracle Corporation, 2017)

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MySQL

It is the most popular open source database on the market, plus it is fast, robust and flexible. Currently, it belongs to Oracle Corporation.

It is ideal for creating databases with access from dynamic web pages, for the creation of on-line transaction systems or for any other professional solution that involves storing data, having the possibility of multiple queries (Oracle Corporation, 2017)

NetBeans IDE

It is a development environment, a tool that allows developers to write, compile, debug and execute programs in the Java programming language, but can be used for any other programming language. NetBeans IDE is a free product with no restrictions of use. (NetBeans IDE, 2017)

Java Media Framework

It is a library that enables audio, video, and other time-based media to be added to technology-based Java applications and applets. This optional package, which can capture, playback, stream and encode multiple media formats for developers. (Oracle Corporation, 2017)

IText

IText Software is a specialist and global leader in programmable PDF software libraries. The iText solution was designed by the visionary Bruno Lowagie in 2000 and has seen continuous growth in its 15 years of existence.

With iText, you can create, expand, extract, split and interact with any PDF file. (IText Group NV, 2017)

GPS

The GPS is a satellite positioning system developed by the US Department of Defense, designed to support precise navigation and positioning requirements for military purposes. At present it is an important tool for navigation applications, positioning of points on land, sea and air.

By means of this system it is possible to determine the coordinates that allow placing the Multiple Care Center within the credentials and thus provide an excellent location in the event of an incident (INEGI, 2017)

Webcam

A Webcam is a front-facing video camera that connects to a computer normally via USB or that is built into a laptop or desktop display. It is widely used for video call programs, as well as to continuously monitor an activity and send it to a Web server for public or private viewing. The webcams usually have a built-in microphone in the unit, or an external microphone comes in the package. (PCMag Digital Group, 2017)

Research Methodology

Type of Research

The work carried out is based on applied research for our study object, which is the development of the system.

The sources used for the project were based on:

- The case investigation is carried out with focus on the multiple care center No 48.

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Theoretical Methods

The analytical-synthetic method is used because the problem to be analyzed is divided into several parts and then integrated according to the Top Down design.

Software Development Methodology

An agile software development methodology is implemented, taking the frames of the SCRUM model.

SCRUM is an agile framework for completing complex projects. SCRUM was originally formalized for software development projects, but works well for any complex and innovative work environment.

With regard to this agile development methodology, the following roles are intended to be assigned to all those involved in the development of the system

• Product Owner = Director in charge of the "Ignacio Manuel Altamirano" school.

• ScrumMaster (the Facilitator)

• Managers

• Scrum Team = Students of the Engineering Degree in Computer Systems.

Times of iterations of variant character that conform to the development of the project, will be implemented:

- Stand-up meeting: Meeting where the general state of the project will be reviewed.
- Sprint: It is the time in which the work of the activity in turn is carried out.
- Sprint Review: Review activity status and product demonstrations.

Steps to Implement

The following steps are required:

- Requirements analysis: Analysis of customer needs.
- Design of the system: Development of the structure of the system.
- Development: Phase where program and build the system.
- Testing: The correct functioning of the system is checked.
- Implementation: Stage where the system is implemented in CAM No. 48.

Results

Then the results of the system, which comprise the functional software, are manifested.

The appearance of the system has an easy-to-understand menu of options as shown in figure 1.

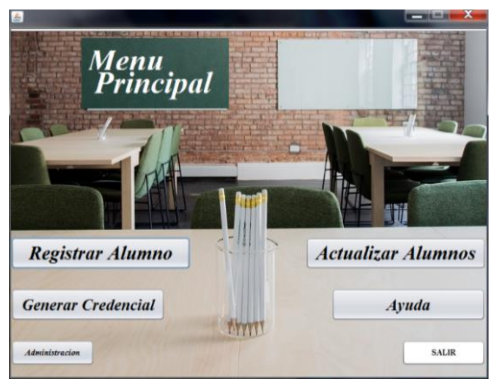

Figure 1 System main menu

The register student option allows the capture of the information of a new student in the database, the required fields are shown in figure 2.

Figure 2 Student registration interface

To take the photograph is linked to a module through the "Capture Photo" button that makes use of a webcam connected to the computer, in this module the image is displayed (see figure 3) for later capture as a file and saved in the database.

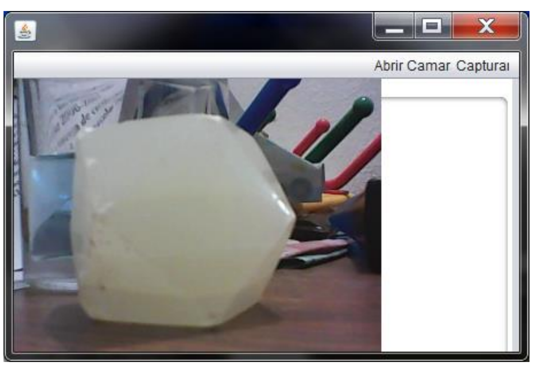

Figure 3 Image capture interface

When you save the new student's record, a QR is automatically created that contains your information and the links that are redirected to Google Maps. In the Update students section of the system, it allows the editing of student information (see figure 4), as well as updating the photo and the QR.

Figure 4 Student Update Interface

In the credential generation section, two file types are created for printing, the first contains the credential and badge in the same document, while the second is sectioned into four sheets for special printing on PVC cards with a laser printer using a configuration previous.

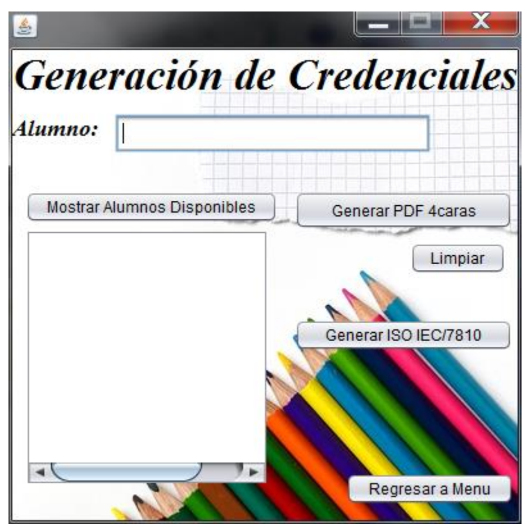

Figure 5 Credential Generation Interface

As a result two documents are generated which are the credential and the badge, as you can see in figure 6.

a)

b)

Figure 6 a) Credential; B) Gafete

When QR codes containing these documents are scanned and without an internet connection, a complete student information file (see Figure 7) is shown, as well as two links that redirect to the Google Maps application which show the Route from the location where the code is scanned to the address of the student's home and school (see figure 8).

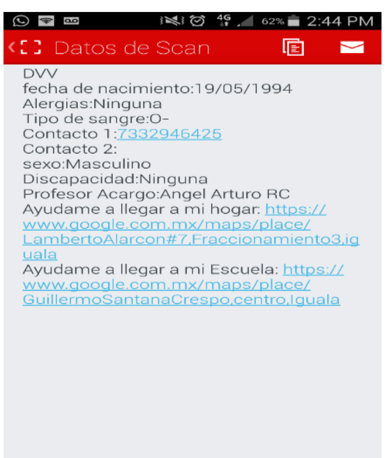

Figure 7 Recorded scan QR scan

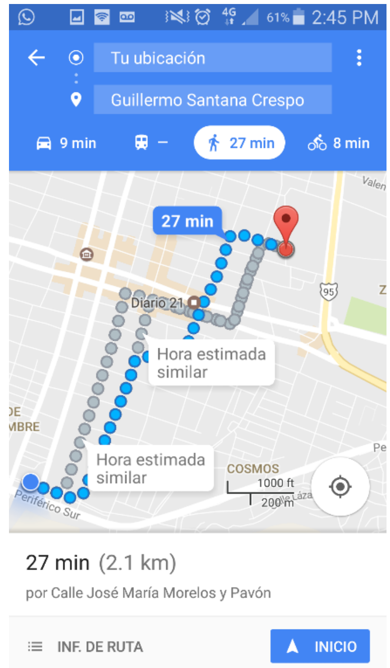

Figure 8 Route shown in Google Maps

In addition to the sections shown, there is a help section containing videos showing the execution of various processes, also has an administration section that allows adding, modifying and deleting users with access to the system.

The images contained in the interfaces backgrounds are owned by Pixabay under the public domain CC0 1.0 Universal, which can be found at the following link: https: //pixabay.com/es/service/terms/#usage .

Conclusions

So far, a fully functional version of the system has been implemented and corresponding training has been carried out to enable CAM 48 staff to create identification documents for their students for the 2017-2018 school year, which represents a number of benefits for The institution, parents and especially students with various disabilities, promoting the participation of academic bodies in the generation of projects that benefit society and encourage the participation of students of the Technological Institute of Iguala to strengthen their Knowledge and skills.

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Automation system for social service using CMMI

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Abstract

The Universidad Autónoma de Tlaxcala since its start has included Social Service in all its careers, and since 2012 has included Social Service as a Learning Unit. Due to some problems detected, arises the need to automate the process, to allow the improvement of costs, time, as well as the digitized information of the entire process. This article presents the system developed to solve this problem, in order to improve the handling of information of Students, Faculties and University Extension. This project was developed by students of Computer Engineering with the follow-up of teachers, and has as key challenge the use of CMMI-Dev Level 2, to maintain and guarantee quality in the project. Currently the project is concluded and implemented in the page of the Universidad Autónoma de Tlaxcala and has been trained to each user.

Automation System, CMMI, Quality, Social service, Experimentation with Software Engineering

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Introduction

This article focuses on the development of a system to automate the Social Service process (SSS), allowing for the improvement of services. For the development of this project, different related works were reviewed, for example Integral System of Social Service of the Universidad Autónoma de Tamaulipas (SISS), is a web application that serves to manage the information of the Social Service process of the borrowers of the Universidad Autónoma de Tamaulipas. The SISS provides an easy and intuitive way to capture reports [1]. The General Direction of Educational Guidance and Assistance DGOAE [2], is an Information System of Automated Social Service in which students of the UNAM can consult different institutions that have agreement with the university, where they can perform their Social service. Finally, there are Automatic Integral Libraries Systems [3] that are composed of several modules, which are designed with the objective of helping to improve the different activities that a library performs.

Justification

The project SSS will automate the current process of Social Service of the university, the project benefit to administrators of University Extension, teochers for Faculty and Students. The most relevants activities are

- The system stores information of dependencies and associated programs valid.

- The system saves a considerable amount of paper and space for each student who performs their social service.

- SSS stores all the digital documents of the process.

- SSS is link with the Integral System of Administrative Information (SIIA) to obtain datas and documents such as Birth Certificate, Study Certificate.

- SSS manages the whole process of social service, from the request until the generation of evidence of conclusion.

Problem Definition

The Social Service is an indispensable requirement in the formation of university students; the process that follows is tedious, reason why it generates great problems in terms of time, administration and resources for students. The Social Service area noticed that there was a clear need for a system that regulates the processes digitally, able to manage the files, and avoiding excess physical documents. For each student the documentation is validated, and an automatized system would effective for this activity, facilitating the organization of the file in a digital way. Due to the need to check the status of the student, it requires certain information that was originally handled with certified document, which could be omitted by unifying the system of academic information of the student and the Social Service System, so that in some way there would be a reduction of costs in the process.

Proposed Solution

Figure 1 shows an overview for the Social Service System. (SSS)

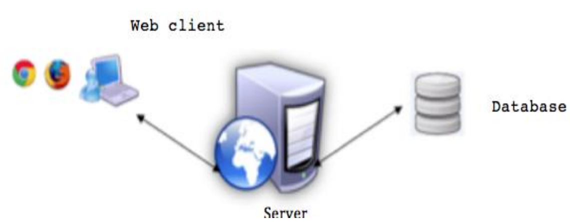

Figure 1 Diagram of the proposal

Web Client: Supports browsers like Mozilla Firefox and Google Chrome.

Web Server: Apache Web Server

Database: ORACLE.

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CMMI

In order to minimize risks in project development, efficiently manage requirements changes and maintain quality acoording to customer expectations, it was decided to use a methodological process under CMMI-Dev Level 2. In this way, it is posible identify the processes that are transversal in all phases of the project [4], [5] and [6]. The process areas used in the Social Service Systems are: Configuration Management, Measurement and Analysis, Process and Product Quality Assurance, Requirements Management, Monitoring and control of the project, and Planning.

• The purpose of Configuration Management (CM) (CMMI-DEV) is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits

• Measurement and Analysis (MA) develop and sustain a measurement capability used to support management information needs.

• Process and Product Quality Assurance (PPQA) provide staff and management with objective insight into processes and associated work products.

• Requirements Management (REQM) (CMMI-DEV) is to manage requirements of the project's products and product components and to ensure alignment between those requirements and the project's plans and work products.

• Monitoring and Control (PMC) provide an understanding of the project's progress so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan.

• The purpose of Project Planning (PP) (CMMI-DEV) is to establish and maintain plans that define project activities.

Identified Requirements

After knowing the Social Service process, 16 Functional Requirements were identified for the development of this project, as well as 3 main users: University Extension, Students and Faculty. We have divided the project in three modules, according to the users the following is the list of Functional Requirements:

Module	Objective
UNIVERSITY EXTENSION	Create period
	Register Dependency
	Generate Certified of termination of SS.
STUDENTS	Fill the Document of Social Service Request
	Generate the document Social Service Request.
	Validate the data of the Request.
	Generate registration format of the Social Service.
	Fill the document of Program Control
	Carry out the report of activities of Social Service
	Generate the document of activities of Social Service.
FACULTY	Validate the Request of Social Service
	Validate the Registration of the Social Service and documentation.
	Validate the Registration of the Social Service
	Validate Letter of Acceptance
	Validate Monthly Reports
	Validate Conclusion Letter

Table 1 List of Functional Requirements

In addition, the following non-functional requirements were identified, quality requirements that all projects must have, and are considered in this project:

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Interface with User, Interfaces with other software or hardware, Reliability, Efficiency, Maintenance, Reusability and Design and Construction Restrictions.

Used Technology

The following technologies were used for the design and implementation of the proposal.

1. Java Enterprise Edition, is a programming platform that allows the use of architectures of distributed N layers [7].

2. Netbeans 8.1, free environment for developing desktop applications, mobile and web applications java, HTML5, JavaScript and CSS [8].

3. WildFly 10 as it is flexible, lightweight and managed that implements the specifications of the Java Platform Enterprise Edition 7. It includes ready-to-run versions of Apache, WildFly, MySQL, Java and required dependencies.

4. Oracle Database 10, as an object-relational database management system, developed by Oracle Corporation, manages: transaction support, stability, scalability, and muti platform support [10].

5. The first-class component library 6.0 and the JavaServer Faces (JSF) primefaces extensions 4.0.0 library were used in the design of screens since it has a set of components for the creation of web applications [11].

6. The Jasper Reports version 6.1.1 library was used for generating reports, it helps to create documents ready to print in a simple and flexible way from a Java application [12].

Architecture

In general, the architecture of the Social Service System is composed of three large layers that in turn are divided into sub-layers.

The first is the layer of the model, which contains the data access sublayer and business logic, the middle layer is a web services layer, it exposes the functions that define and solve the model, so that a Third layer, which is the user interface, can make use of them. The three layers are independent, which facilitates the implementation of different user interfaces, depending on the technology required by the client.

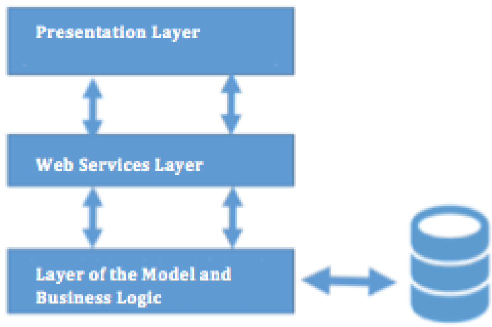

Figure 2 Architecture

Social Service System

The following solution was proposed from the presented problem, here is a brief description of the development of the system. It is important to mention that we use the code conventions suggested in [13] to maintain the quality of the project. As already mentioned, users and modules are: University Extension, Students and Faculty. We describe each module.

University Extension Module

In the University Extension Module, the user has permissions to create period, register dependencies and generate certificates of termination of Social Service

Figure 4 shows a list of periods made by University Extension.

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Figure 3 List of periods

Figure 4 Shows the screen to create a new period.

Figure 4 Create a new period

Faculty Module

The Faculty user can view and validate the documents uploaded in the system by the Student user. Figure 5 shows the list of applications belonging to the Faculty Module. From this screen can be checked each student's file, the Faculty user can validate or reject the documentation, in addition to viewing the documentation status per student.

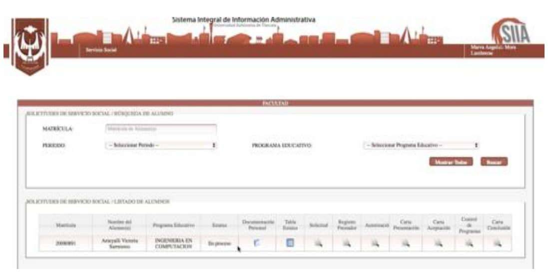

Figure 5 List of Applications

Student Module

This user will be able to consult his personal information, besides request and generate the documents corresponding to his Social Service. Figure 6 shows the screen in which the student can register the request, these data are of great importance, since the documentation generated will be based on this information.

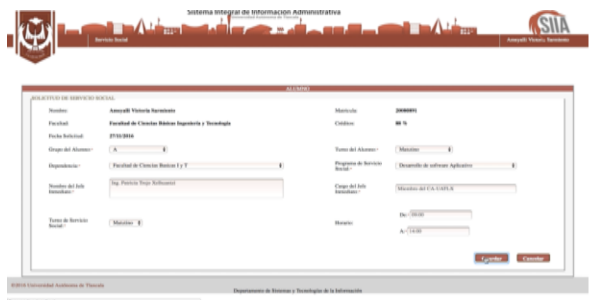

Figure 6 Application for Social Service

Figure 7 shows the list of documents to be covered by a student, the system is designed to accept documentation in PDF format, this documentation will be validated later by the user Faculty.

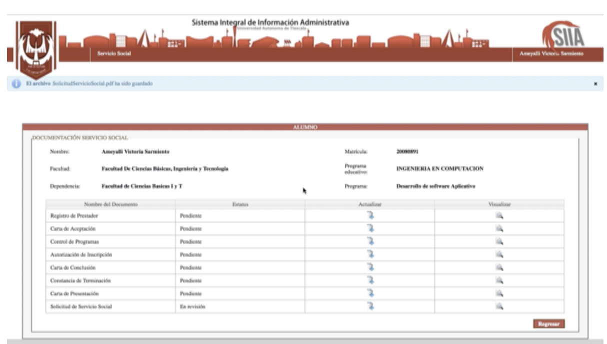

Figure 7 Documentation for Social Service

Once the process is completed and validated in the System, the certificate of conclusion of the Social Service is generated, which is delivered to the students by the University Extension team.

Tests

At the end of the Social Service System, we did Modular Testing, Integration Testing and System Testing. To receive the letter of complete satisfaction the tests had some iterations until they were No Defects Found.

Conclusions

The present system has the purpose to optimize and improve the Social Service process, it represents a great support for the students, coordinators of the Faculties and work team of Social Service, it includes a great interaction with the users and we know that its impact will be interesting, because it reduces the time and cost of process, in addition, having a system that manages the documentation of students reduces physical space and workload. The automation of this process is a important advance for the university, this project is in operation, but it is open to continuous improvements. This system ensures a more efficient and simple work thus obtaining the satisfaction of the users. This system is not to replace human contact, it manages the information in order to facilitate its storage, access and modification.

Finally, this project is a result of the collaborative work of teachers and students, the challenge was to use CMMI-Dev Level 2 to maintain quality in the project. We consider that this experience has been of great benefit to the team. The project is already implanted in the page of the Universidad Autónoma de Tlaxcala and the users have been trained: Faculty Coordinators, work team of University Extension and Students who will start their Social Service in August of this year.

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Virtual world of mexican cinema

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Abstract

Virtual reality is an artificial computer-generated environment in which users are able to interact with each other by means of characters and manipulating objects, the scenarios built by computer are known as virtual worlds. This document presents the design and construction of a virtual world focused on the theme Mexican Cinema, in a way of Virtual Museum. This Virtual Museum has five rooms: Sound Film, Golden Age Cinema, Transition Period, New Mexican Cinema, as well as a virtual cinema that presents shorts of some films representative of the Mexican Cinema, this museum is staged by means of 3D objects, photographs, videos and allows the interactive navigation of the user through the virtual world, in order to publicize the most relevant facts of Mexican Cinema.

Virtual Reality, Virtual World, Virtual Museum, Mexican Cinema, Stages of Cinema

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Introduction

The virtual worlds have the possibility to represent mirror worlds, or imaginary world, etc. Currently virtual worlds together with Virtual Reality open a new stage of development for the creation of systems and education. Through the inclusion of Virtual Reality, all this is possible to recreate educational centers, shopping centers, recreational places, etc. Specifically, this project focuses on the history of Mexican Cinema, the idea of this project is to develop a virtual museum about the history of Mexican Cinema, considering films created, important personages, history of the cinema, cinematographic equipment used for the projections of the films.

Some related works of this project is the Virtual Museum for the Bastion of Solitude of San Francisco, Campeche [1], this museums focuses on the culture and history of Mayan architecture, created as didactic material in institutions, also for the interaction of people from other parts of the world. A second work is the virtual visit to the Palace of Fine Arts of Mexico City [2], created to carry out the virtual visit by the general public. Finally, the project "Virtual Visit to the Vatican" [3], includes photographs of art jewels of all time.

Virtual Worlds

[4] describes a Virtual World as a 3D environment, which simulates the real world in terms of topography, social and economic conditions and communication, but do not have limitations. In [5] is said that virtual worlds offer a way of escape, fantasy, socialization, collectivity and, in some cases, a source of income, are similar to real in the sense that they contain all types of human social interaction, including friendship, love, economics, war, politics, etc.

Characteristics of virtual worlds according to [6]:

• Interactivity. The user is able to communicate with other users.

• Corporeity. The environment is subject to certain laws of physics, and has limited resources.

• Persistence. Although there is no user connected to metaverse, the system still works and will not stop. The user´s position is saved.

Our project uses corporeity.

Museums

In [7] it is commented that the role of museums as preservers of objects is essential, so is the information about their collections.

There are five generations of museums [8]:

- The first generation of museums is characterized as scientific and technical, it presents the classic concept of storing precious pieces, rare items, masterpieces of nature or man.

- The second generation includes technological museums, based on the Industrial Revolution and the artisan classes.

- The third generation introduces the interaction, centering in the experience visitor.

- The fourth generation can be identified as incorporating scientific theme parks. Its most prominent feature is the combination of information, education and entertainment in a product.

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- Finally, the fifth generation uses the media, audiovisual show, special effects, surround sound techniques, virtual reality spaces resulting in scientific communication and education. Likewise, technology has led to the generation of fully virtual museums, where the physical museum is not relevant.

The Mexican Virtual Cinema is located in the fifth generation, since the physical location does not exist and Virtual Reality is used.

Virtual Museums

The advance of the new virtual environments means, without doubt, a radical transformation in the conception of the museums. The most revolutionary idea of digital technologies is interactivity. Interactivity is the option of manipulating virtual objects and allows us to navigate the contents to the user's rhythm [9].

Virtual worlds based on 3D technology have always brought a halo of novelty, creativity and recursion when it is used [10]. Originally, intended for the video game industry and simulators of all kinds, such as health, aviation and education. Currently, some virtual worlds have been developed for the user's knowledge, interactivity and the development of imagination. There are different projects of virtual museums most of them are photos in 360°, some are not totally developed in 3D.

Mexican Cinema

The Mexican Cinema is a Film Production made in Mexico or abroad with Mexican budget. The Mexican Cinema excels in Latin America, it started with silent films in 1896. In 1929 was introduced the sound film. One of its best known periods is the Golden Age from 1936 until 1957, Golden Age reached the internationalization. In 1952 themes of fighters were introduced. In the late 1950s and early 1960s emerged the rock and roll movies.

At the beginning of the sixties the UNAM created cineclubes in Mexico and in 1963 founded the University Center of Cinematographic Studies. In 1970 the film was used as national and international media, a time known as State Cinema. The private film industry emerged between the seventies and eighties, it was characterized by the production of low cost films, in short time and low quality. The film produced on the northern border known as Cabrito Western was produced in the eighties [11], [12]. In 1983, the Mexican Institute of Cinematography (IMCINE) was created to produce quality films. Mexico currently has a good time in the cinema, the number of films made each year is greater, in 2013, Mexico made 126 films reaching a historical maximum from the Golden Age [13].

Methodology

For the development of this project, we use a sequential methodology, the methodology consideres that the project is of the Area of Virtual Reality with a defined theme: Virtual Museum of the History of Cinema.

1.-Analysis of requirements	2.-Design and modeled	3.-Implementation	4.-Tests and Corrections:
Goals: A) Selection of museum areas B) Selection of museum pieces C) Selection of references			
Hardware A) Developed B) User	**A) Design and modeled of software**		**A) Unitary**
Software A) Developed B) Of application	**B) Design of material:** Photographic Galleries, videos, text, Descriptive audios, 3D models, texturized, markers, images	**Codification**	**B) Integration** **C) Functional**
Principles of Usability [8] A) Interaction B) Presentation C) Navigation D) Panoramic E) Sound F) Orientation and help	**C) Interface Design**		**D) Usability** **E) Corrections**
Principles of Usability A) Interaction B) Presentation C) Navigation D) Panoramic E) Sound F) Orientation and help			

Figure 1 Methodology

Detailing the methodology:

1- Analysis of requirements consider:

Specific goals in this case selecting areas of the museum, key parts and literature to supplement the original information.

Definition of hardware of development and end-user

Definition of software of development

Define principles of usability considering interaction, presentation, navigation, panoramic, sound, guidance and help [14].

2. Design and Modeled of software: UML, 3D objects, as well as taking into consideration usability aspects.

3. Implement

4. Finally, like all quality software is important to realizate different tests as: unitary, of integration, functional, of usability. Also it is necessary correct each problem detected.

Virtual Museum Of Mexican Cinema

In this project was developed a virtual world on the history of Mexican Cinema, it is directed all the people. For the development of this project, we investigated was about of Mexican Cinema, Virtual Museums and Virtual Reality. The project is developed in Blender [15] and Unity 3D [16], both compatible with each other. Figure 2 shows a General Diagram of the project, which is composed of 5 important scenarios: Sound Film, Golden Age, Period of Transition, New Mexican Cinema, in addition a Virtual Cinema.

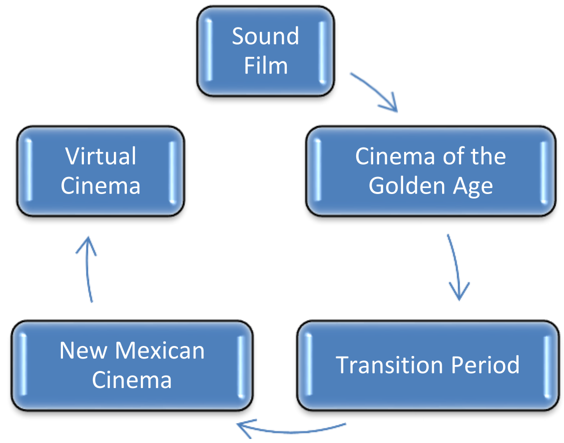

Figure 2 General Diagram of the Virtual Museum of Cinema

Virtual Museum of Mexican Cinema

Figure 3 shows the main entrance and the gardens of the Museum of Mexican Cinema.

Figure 3 Main entrance of the Virtual Museum of Mexican Cinema

Virtual Sonorous Film Room

The Sound Film began in1929, with the incorporation of synchronized sound, this project includes a Virtual Room of the sound film with photographs and history, see Figure 4

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Figure 4 Room Sound film

Virtual Room of the Golden Age of Mexican Cinema

The Golden Age of Mexican Cinema began in 1936, in this time the Mexican film industry had high levels of quality, it corresponds to the second room of the Mexican Virtual Museum, the room contains information on films, actors, cameramen, writers and characters, we use photographs, 3D models, text and audio.

Figure 5 Room of the Golden Age

Virtual Room of transition of the Mexican Cinema

The 1960s was a stage of transition for Mexican cinema, in this time emerged new filmmakers, the fils produced in that decade reflect the search for new forms of expression.

Figure 6 shows the Virtual Room of the Mexican Cinema transition, the Virtual Room presents propaganda of different films of this time. In this area are reproduced short films and historical information.

Virtual Room of Modern Cinema

In the 1990s, Mexican Cinema recovers with highly critical films, a new generation of filmmakers, actors, writers, technicians and spectators emerge. 3D models, actors' photographs, films, as well as information of the time, and short films of the New Mexican Cinema, are shown in the Virtual Room of the Modern Cinema, see Figure 7

Figure 6 Virtual Hall of the Transition Period

Figure 7 New Mexican Cinema Room

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Virtual Mexican Cinema

Inside the same museum there is a virtual cinema in which the user can reproduce shorts films of the Mexican Cinema, see. Figure 8.

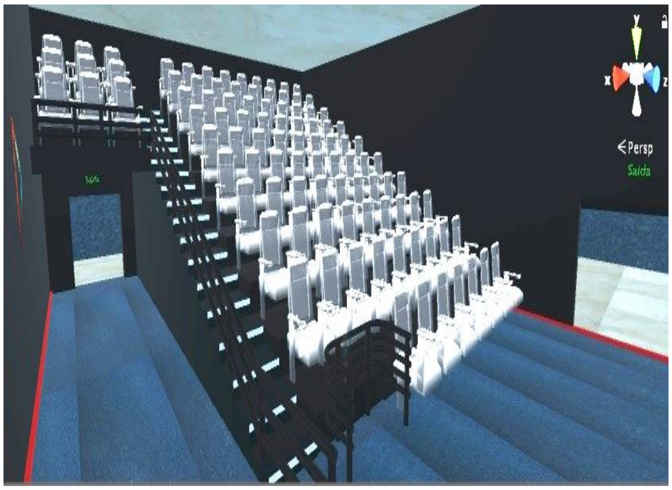

Figure 8 Virtual Cinema where films shorts are projected

Tests And Results

During the tests, we reviewed 3D models, we checked that the models did not have any Bug, as well as, we reviewed each structure of the buildings included in the Virtual World, the possible faults of the audios and videos udes in the Project. By way of example, we reviewed that the buildings in project not contained unsuitable transfers of light. When doing this test, we noticed that in the buildings when putting the sun light some shadows of the other 3D objects were reflected. The problem was fixed by modifying the texture of UI Text to TextStandard. In the same way, we performed unit tests in each room and tests of integration.

Conclusions

The technology is giving contributions in many areas, benefiting in education and culture, enabling citizens to be better informed. However, even in today's museums of Mexico, this effort is still inadequate, much work is required to improve the goals that technology imposes on us.

In developing this project, we can see the potential of Technology, especially in the area of Virtual Reality, we have the possibility to show different historical and cultural scenarios. Through research, we have know that people have low level knowledge of historic of Cinema, so it is important to publicize the cinema using different tools. The Virtual Museum of Mexican Cinema is created for the general public.

For the development of this project the cascade methodology was adapted, in this work we have incorporated key aspects for using Virtual Reality in a museum.

In general, Blender and Unity met the expectations, due to both tools are viable for the development of Virtual Reality.

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Handling robotic system composed by robots petit

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Abstract

This paper presents the development of a handling system with 3 fingers anthropomorphic 4 degrees of freedom, controlled through a graphical interface. The study of direct and inverse kinematics, simulation, assembly and command system thereof, have been made; to ensure anthropomorphic finger movements, a design previously made, has been used. The restrictions have human fingers, as the rotation between each phalanx, have been considered, also the natural coupling between the penultimate and final joints. The graphical interface has been implemented in MATLAB®, the design of the components of the prototype has been made in SOLIDWORKS® and ARDUINO® MEGA2560® has been used for serial communication with the servo motors in the system command. This system allows noting the work performed and is a basis for the development of future robots, robotic systems and applications.

Robotic Handling system, modeling, design, interface, simulation

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1. Introduction

An important part in the realization of this project is the study of direct and inverse kinematics that allows to know the paths of the human finger simulating it, the control of a manipulation system, made up of 3 anthropomorphic fingers, which are controlled by means of the GUI designed with MATLAB® software, also emulates the movement of human fingers.

The human hand is very complex since its study involves the behavior of muscles, bones, tendons and ligaments, in order to obtain a functional design. It is noted that the fingers have been the fundamental basis of previous studies. In the proposed design, the three phalanges of the fingers and their joints were considered. In particular, the aspects related to direct and inverse position modeling are discussed.

1.1 Justification

As part of the development of the project "Design and construction of robots, robot telemanipulation devices and robotic systems for manipulation", the work presented in this article is included. In particular, it is emphasized in the design of robotic systems for manipulation.

1.2 Problem

Obtaining a robotic manipulation system composed by three petit robots, with a total of 12 degrees of freedom, commanded through a graphical user interface that incorporates the geometry designed in computer aided design software.

1.3 Hypothesis

A robot manipulation system will be obtained by using robotspetit, direct and inverse kinematic modeling, high-level language and interactive environment for numerical calculation, visualization and programming, MATLAB®, SOLIDWORKS® computer-aided design software and ARDUINO® MEGA2560® board.

1.4 Objectives

1.4.1 General objective

Design a robotic system to manipulate objects using 3 robots petit.

1.4.2 Specific objectives

- Design the robotic manipulation system with 3 robots petit in solidworks.
- Determine the direct and inverse kinematics of the robotic system.
- Develop the graphical user interface to be able to command the 12 servo motors of the handling system manually.
- Perform tests in simulation.
- Perform validation with the robotic system.

2. Background

As a complement to the previous work support at the Technological Institute of Nuevo León, it can be first mentioned that in (Jiménez Villalobos & Ramírez De La Cruz, 2005) the construction of a robotic arm of three gdl (degrees of freedom) type puma (programmable universal manipulator for assembly).

Equations have been developed for both the direct kinematic model and the inverse kinematic model. Using the Lagrange equations, we have obtained the equations of the dynamic model.

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In the architecture of this robot it is observed that there is a pair of articulations with parallel axes. Then in the work developed in (Cimadevilla Lajud & Pérez Herrera, 2006), it is mentioned that it has been tried to reproduce some limbs of the human being for medical purposes or for the industry. Spatially the hand, this being of paramount importance for everyday activities has become a research topic, robots have been built but to this day has not been able to imitate their skills.

To address the problem of inverse kinematics, the authors consider a finger with three degrees of freedom. The finger develops its motion in an x-y plane, which simplifies the solution of the inverse kinematic model, since the analysis focuses on the configuration of the three joint variables that allow the desired point to be reached (P_x, P_y). However the system turns out to be redundant in a degree of freedom, so the problem lies in how to resolve such redundancy.

In (Aguilar Acevedo & Ruiz González, 2011), the direct kinematic model is shown. The direct kinematic problem is reduced to finding the transformation matrix that relates the coordinate system of the link to the coordinate reference system.

Then in (Cuevas Ramírez, Ramírez Vargas, & Cruz Hernández, 2012), a project involving the design, construction, and control of a 4-degree-of-freedom manipulator arm is presented. The project is divided into 3 stages, the first is the design and mechanical construction of the robot manipulator, the second is the instrumentation and implementation of the control system and the third corresponds to the adaptation of the manipulator arm to a mobile robot to have a robot of Exploration and safety.

In (Suárez & Grosch, 2003) is presented the description of the mechanical hand called MA-I (Intelligent Artificial Hand) as part of an integrated system for the experimentation and testing of strategies of apprehension and manipulation of objects.

As previous developments in the institute, the design of a robotic finger, with anthropomorphic movements, has been presented in (Hernández Hernández, Garcia Andrade, Fernández Ramírez, & Cuan Duron, 2014) and (Hernández Hernández, Garcia Andrade, & Fernández Ramírez, 2014).

Later in (De Leon Treviño, Garcia Andrade, Fernández Ramírez, Cuan Duron, & Urquizo Barraza, 2015) and (Gomez Perez, Fernández Ramírez, Cuan Durón, Urquizo Barraza, & García Andrade, 2016), a robotic grip system is presented, in that system, two robotic fingers are integrated adaptations are made in hardware, electronics and software.

3. Methodology

In this case, the manipulation system is mathematically modeled. In particular, the equations of direct kinetics and inverse kinetics are obtained.

The D-H parameters are used to obtain the matrices of homogeneous transformation and these to be able to calculate the direct kinetics. In the case of reverse kinetics, the natural coupling that exists in the movement of the middle and distal phalanges, allows us to determine the solution of inverse kinetics as the intersection between two circles. The robot petit is used in software SOLIDWORKS® , to assemble the robotic manipulation system composed of 3 robotspetits. It is worth mentioning that the robot petit, has also been designed in soliworks.

The interface is designed in Matlab, to be able to command the twelve servomotors of the system. The communication is done using the serial port so that ARDUINO® MEGA2560® transform the configurations of robots petit in movement in each one of the degrees of freedom.

3.1 Forward kinematics

In the kinematic modeling of position of a manipulating robot, the relations between the operational space (in which the location of the terminal organ is defined) and the articular space of the robot (in which the configuration is defined) are established.

The direct model is the relation that allows to determine the vector x of operational coordinates of the robot corresponding to a given configuration q.

$$\mathbf{x} = \mathbf{f}\,(\mathbf{q}) \quad (1)$$

The direct geometric model of a robot can be obtained from the homogeneous transformation matrix of the robot defining the frame n of the terminal link with respect to the frame 0 of the base of the robot. In the case of simple-structure robots, the transformation matrix is given by:

$$^{0}\mathbf{T}_n = {}^{0}\mathbf{T}_1\, {}^{1}\mathbf{T}_2 \ldots {}^{n-1}\mathbf{T}_n \quad (2)$$

The transformation matrix $^{f}T_E$ defines a frame of the tool of the terminal organ E with respect to a fixed base f, this matrix can be calculated by:

$$^{f}\mathbf{T}_E = \mathbf{Z}\, {}^{0}\mathbf{T}_n\, \mathbf{E} \quad (3)$$

3.1.1 Forward kinematic modeling of robots petit

The D-H parameter tables for robot petit 1, 2, 3, which constitute the manipulation system, are shown next in tables 1, 2 and 3.

Link	α_i	d_i	θ_i	r_i
1	0	0	θ_1	0
2	90º	0	θ_2	0
3	0	4	θ_3	0
4	0	3.9	θ_4	0
5	0	1.5	θ_5	0

Table 1 DH Parameters for robot petit 1

Link	α_i	d_i	θ_i	r_i
1	0	0	θ_1	0
2	90º	0	θ_2	0
3	0	4	θ_3	0
4	0	3.8	θ_4	0
5	0	1.5	θ_5	0

Table 2 DH Parameters for robot petit 2

Link	α_i	d_i	θ_i	r_i
1	0	0	θ_1	0
2	90º	0	θ_2	0
3	0	4	θ_3	0
4	0	3.8	θ_4	0
5	0	1.5	θ_5	0

Table 3 DH Parameters for robot petit 3

These parameters of each link i, with i = 1, 2, 3, are replaced in the following formula:

$$^{i-1}\mathbf{T}_i = \mathbf{Rot}\,(\,\mathbf{x},\ \alpha_i\,)\ \mathbf{Trans}\,(\,\mathbf{x},\ d_i\,)\ \mathbf{Rot}\,(\,\mathbf{z},\ \theta_i\,)\ \mathbf{Trans}\,(\,\mathbf{z},\ r_i\,)$$

$$= \begin{bmatrix} C\theta_i & -S\theta_i & 0 & d_i \\ C\alpha_i S\theta_i & C\alpha_i C\theta_i & -S\alpha_i & -r_i S\alpha_i \\ S\alpha_i S\theta_i & S\alpha_i C\theta_i & C\theta_i & r_i C\alpha_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(4)

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Where S is the sine function and C is the cosine function. Figure 1 shows the distances between the bases of each of the robotic fingers that make up the manipulation system once built.

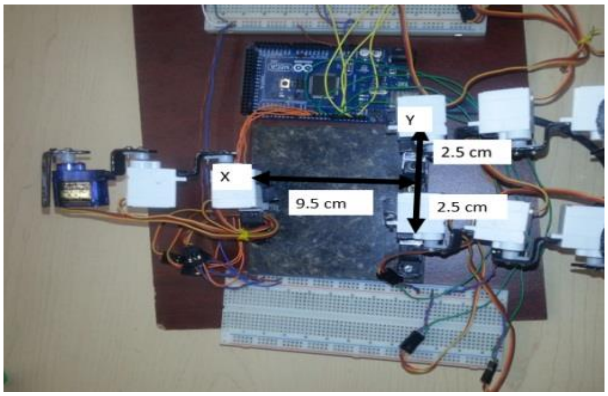

Figure 1 Distances between each finger.

Homogeneous transformation matrix of robot petit 1 with $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0º$.

$$\mathbf{Z}_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 2.5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^0\mathbf{T}_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^1\mathbf{T}_2 = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^2\mathbf{T}_3 = \begin{pmatrix} 1 & 0 & 0 & 3.6 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^3\mathbf{T}_4 = \begin{pmatrix} 1 & 0 & 0 & 3.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^4\mathbf{T}_5 = \begin{pmatrix} 1 & 0 & 0 & 1.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Homogeneous transformation matrix of robot petit 2 with $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0º$.

$$\mathbf{Z}_2 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -2.5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^0\mathbf{T}_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^1\mathbf{T}_2 = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^2\mathbf{T}_3 = \begin{pmatrix} 1 & 0 & 0 & 3.6 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^3\mathbf{T}_4 = \begin{pmatrix} 1 & 0 & 0 & 3.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^4\mathbf{T}_5 = \begin{pmatrix} 1 & 0 & 0 & 1.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Homogeneous transformation matrix of robot petit 3 with $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0º$.

$$\mathbf{Z}_3 = \begin{pmatrix} 1 & 0 & 0 & 9.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^0\mathbf{T}_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^1\mathbf{T}_2 = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^2\mathbf{T}_3 = \begin{pmatrix} 1 & 0 & 0 & 3.8 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^3\mathbf{T}_4 = \begin{pmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \; {}^4\mathbf{T}_5 = \begin{pmatrix} 1 & 0 & 0 & 1.5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In all three cases the matrix **E** is the matrix identity of 4x4.

3.2 Kinematic inverse position model

To obtain the solution of the problem of the inverse position kinematics, in this work, a geometric approach is used. A fixed relationship is used to consider the dependence or coupling of the third and fourth articulations, as mentioned in (Cimadevilla Lajud & Pérez Herrera, 2006), the relationship that was used is the following:

$$\theta_4 = \left(\frac{2}{3}\right)\theta_3 \qquad (5)$$

This allowed reducing the problem of inverse kinematics by calculating the intersections between 2 pairs of circles.

In Figure 2, the working space of one of the robot petit of the system is shown. It should be noted here that in order to obtain this working space, the relation expressed in equation 5 is taken into account.

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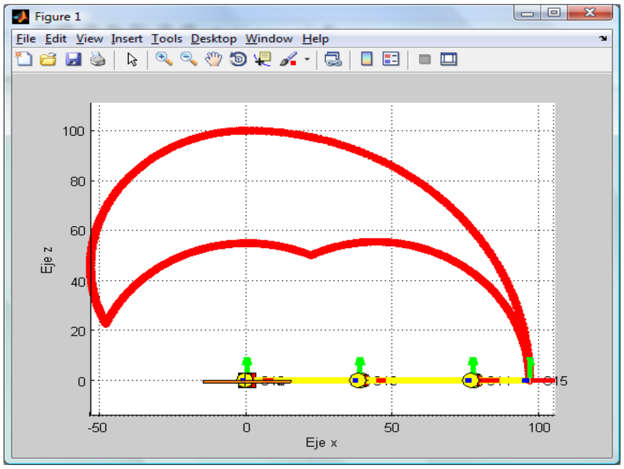

Figure 2 Workspace for each robot petit.

3.3 Manipulation System Modeling.

Petit-robot modeling was done using 3D CAD design software SOLIDWORKS® . Figure 3 shows the different elements or components that were used to assemble the handling system in the SOLIDWORKS® environment.

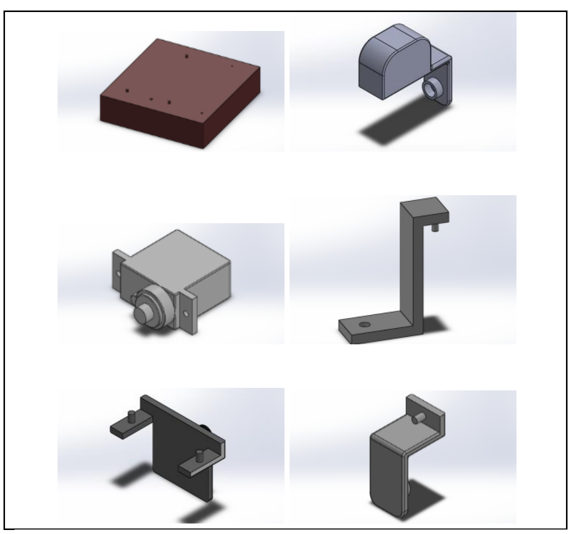

Figure 3 Components for assembly of the manipulation system.

Once each of the robots petit was constructed, the manipulation system was assembled, then in Figures 4-6, the system is shown in some configurations.

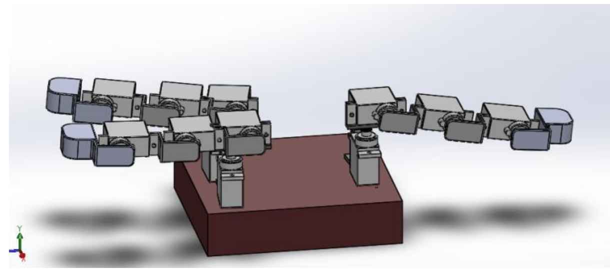

Figure 4 Initial configuration **q** = [0º, 0º, 0º, 0º] for each of the 3 robots.

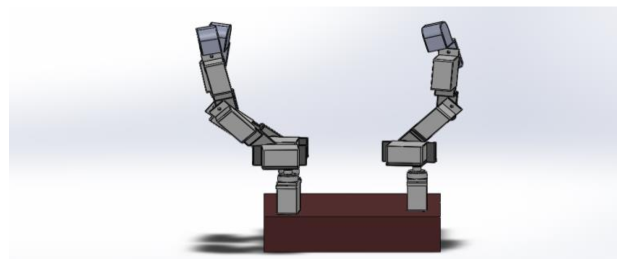

Figure 5 Configuration **q** = [0º, 30º, 50º, 33.33º] for each of the 3 robot petit.

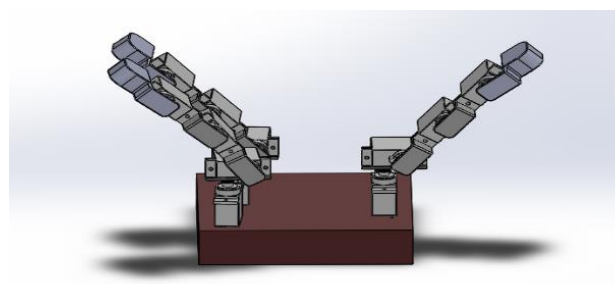

Figure 6 Configuration **q** = [0º, 45º, 0º, 0º] for each of the 3 robot petit.

3.4 Graphic User Interface, GUI

The graphical user interface was programmed using MATLAB® software. Lines for each of the robotic fingers were used to represent each of the phalanges and cylinders for each of the joints. In order to be able to interact with the interface, sliding bars were used, which can be made to vary each of the joint variables of each of the fingers.

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The interface has "+" and "-" buttons, which allow us to solve the problem of inverse kinematics. In Figure 7, the graphical interface is shown for the initial configuration **q** = [0º, 0º, 0º, 0º] of each robot; Figure 8 shows the manipulation system in said configuration.

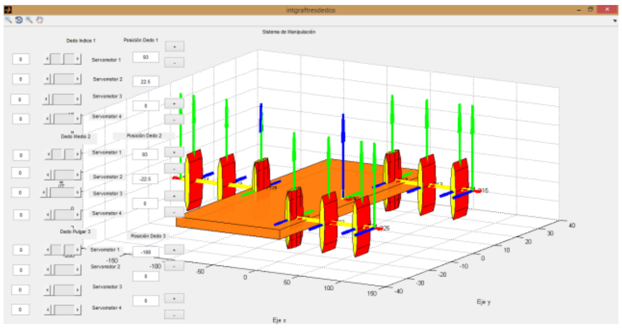

Figure 7 GUI with **q** = [0º, 0º, 0º, 0º] configuration for each robot petit.

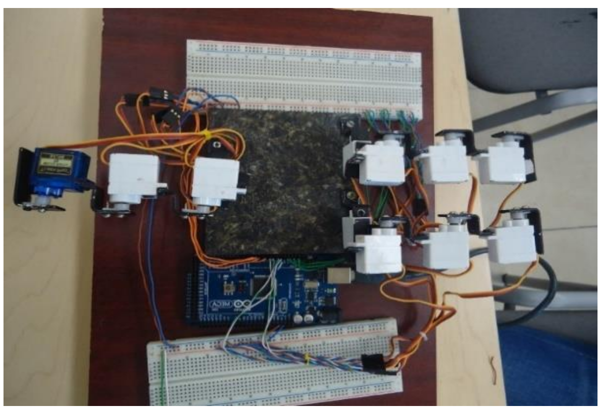

Figure 8 Manipulation system with **q** = [0º, 0º, 0º, 0º] configuration for each robot petit.

3.5 Code

ARDUINO® code used for the operation of the Robotic Handling System.

```
#include <Servo.h>
Servo servo[12];
int pin[12]={
  6,7,8,9,
 10,11,12,13,
 2,3,4,5};
void setup(){
  //servo[0].attach(3);
  for (int i=0;i<12;i++){
    servo[i].attach(pin[i]);
  }
  Serial.begin(9600);
}
int grados;
void loop(){
 if (Serial.available()){
   for (int i=0;i<12;i++){
     grados = Serial.parseInt();
     if(grados>0 && grados < 180){
       servo[i].write(grados);
       delay(50);
     }
   }
 }
}
```

4. Results

With the robotic manipulation system that has been presented, the desired objectives have been achieved; some improvements have been monitored throughout the development of this system.

This robotic system was conceived with the idea of following up on a project of design of construction of mini-robots, previously realized. It has been considered to improve both the design and how to control it through programming. The objective of being able to integrate a more complex robotic system, from the mini-robots previously designed, has been fulfilled.

The number of manipulable degrees of freedom has been multiplied by three, the graphical user interface has been modified for this purpose. The robots petit of the manipulation system move anthropomorphically.

In order to support the results of the developed system, in the graphical user interface as well as in the real robot petit, in figure 9, a second configuration **q** = [0º, 45º, 45º, 45º] is shown; Figure 10 shows the manipulation system in this configuration.

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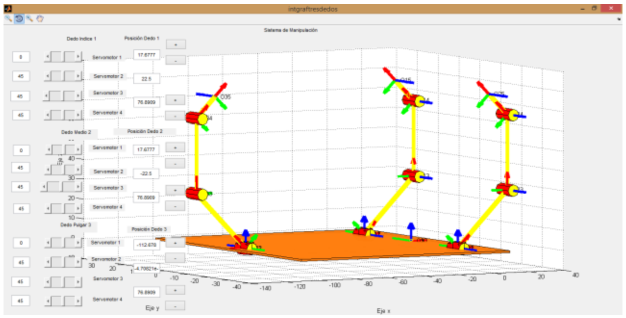

Figure 9 GUI with **q** = [0º, 45º, 45º, 45º] configuration for each robot petit.

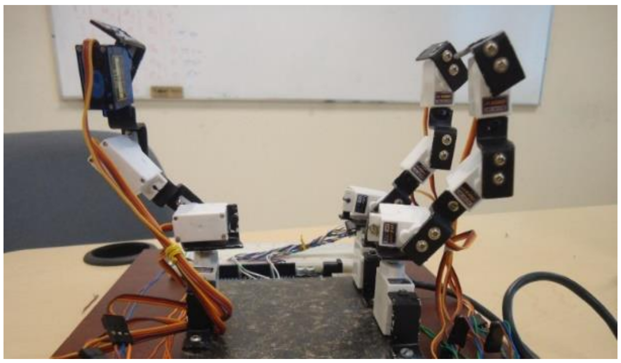

Figure 10 Manipulation system with **q** = [0º, 45º, 45º, 45º] configuration for each robot petit.

In figure 11, a third configuration **q** = [0º, 45º, 45º, 45º] is shown and the manipulation system is illustrated in figure 12.

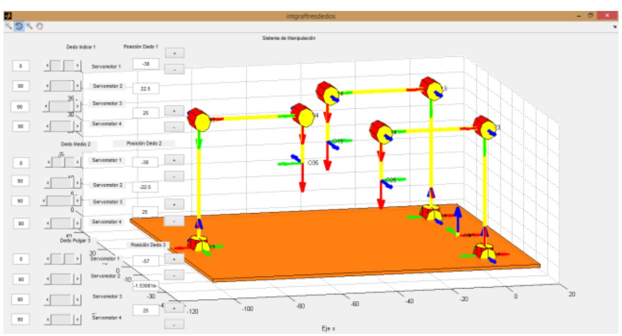

Figure 11 GUI with **q** = [0º, 90º, 90º, 90º] configuration for each robot petit.

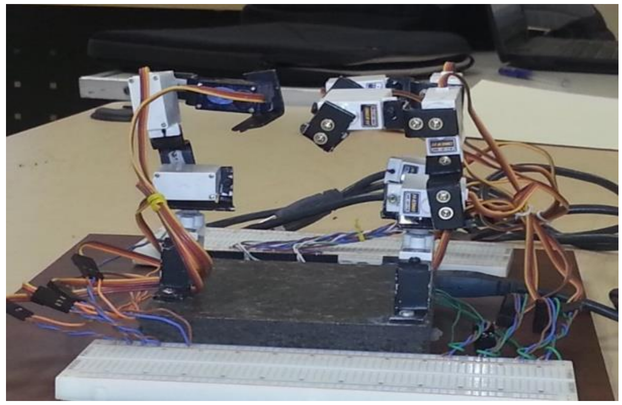

Figure 12 Manipulation system with **q** = [0º, 90º, 90º, 90º] configuration for each robot petit.

5. Conclusions

The dimensions of the links were taken into account and the different models were determined to solve the inverse kinematics and direct kinematics, that is, the calculation of the position considering the joint variables that produce it.

The modeling of the links was done using CAD software SOLIDWORKS® where the design of the system was formed. One aspect that was not taken into consideration when making cuts and folds was the loss of a few millimeters, causing not all links to have the same dimensions, and this in turn, making the assembly specifically for each robot.

Intercommunication via the serial port was also carried out, communicating via MATLAB® and the ARDUINO® MEGA2560® board, controlling it through the Graphical Interface. This allows the comparison of the physical model and the graphical model, since at the moment of giving an instruction so that the manipulation system has a movement. In this comparison, the joint boundaries for each robotic finger were taken into account, as are the angles in which a finger can be moved initially to the end point or limit at which its movement arrives.

Areas of opportunity have been identified, on the one hand improvements in the modeling and design of links, on the other hand can use other type of actuators.

Different ways of telemanipulating the system are also explored.

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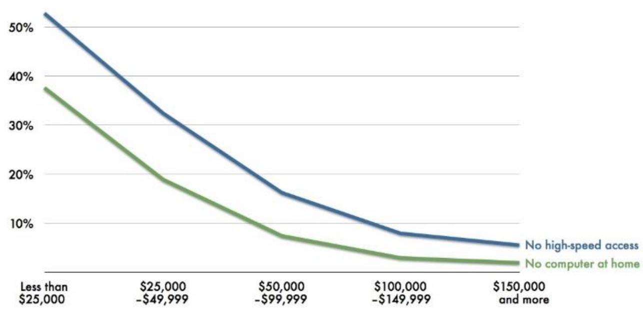

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