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Editorial

¿Programación Paralela Clásica o Nuevos Paradigmas Paralelos para Big Data?

El término *Big Data* ha sido adoptado para representar **los retos** que surgen frente al abrumador flujo de datos que demanda un continuo crecimiento de poder computacional para ser analizado y procesado. Estos retos surgen principalmente debido a: (i) el volumen de datos se expande dramáticamente creando la necesidad de escalar a través de clusters de cientos de computadoras *commodity;* (ii) los datos son producidos desde diferentes fuentes y almacenados en diferentes formatos (i.e., bases de datos relacionales y repositorios NoSQL), lo que genera gran heterogeneidad; y (iii) a pesar del crecimiento en escala y complejidad de los datos, aún está presente la necesidad de consultar esos datos a velocidades interactivas con respuestas en tiempo real.

Este escenario induce a cambios en el paradigma para el procesamiento y minería de datos a gran escala, tanto en las arquitecturas computacionales como en los mecanismos de análisis de datos. Estos cambios han impulsado el desarrollo de nuevas soluciones en el ámbito industrial (e.g., para análisis de datos en la web, mejores servicios en las redes sociales) y ámbito científico (e.g., para simulaciones a escalas masivas, manejo de redes de sensores, análisis de genoma humano).

En este contexto, varias empresas, tales como compañías en Internet y asociaciones de redes sociales, han propuesto sus propios enfoques analíticos, considerando nuevos modelos de programación, desarrollando sistemas y *frameworks* de alto nivel y proponiendo extensiones a las bases de datos paralelas. Estos nuevos modelos de programación son capaces de procesar y analizar tal inmensa cantidad de datos sobre un nuevo modelo de computación en clusters. Se habla entonces de clusters de *Big Data,* como una arquitectura capaz de adaptarse al continuo crecimiento de la cantidad de datos sin afectar el rendimiento de las aplicaciones. Los clusters de *Big Data* se componen de cientos de computadoras susceptibles a fallas (de allí también llamados *shared-nothing commodity clusters*), pero con sistemas que proveen de manera automática la planificación de las tareas de acuerdo a la localidad de los datos, tolerancia a fallas y balanceo de carga.

Los modelos de programación paralela clásicos, tales como maestro-esclavo con pase de mensajes usando MPI (*Message Passing Interface*) y multihilos con OpenMP (*Open Multi-Processing*), aplicados en clusters de computación clásicos –llamados **clusters MPI**–, no son adecuados en el escenario de *Big Data*. Ésto es debido al gran ancho de banda que demanda el movimiento de los datos a los nodos de procesamiento y a la necesidad de administrar manualmente la tolerancia a fallas y el balanceo de carga. Sin embargo, con los clusters *Big Data* combinados con un nuevo modelo de programación paralela, se mejora el desempeño en el procesamiento de datos provenientes de fuentes NoSQL y se reduce la brecha de rendimiento de las bases de datos relacionales. La principal diferencia entre el modelo de procesamiento paralelo clásico y los nuevos paradigmas en el contexto de *Big Data* es que en *lugar de mover los datos, se mueven las funciones de procesamiento hacia los datos*.

El modelo más popular de programación paralela en el contexto de *Big Data* es **MapReduce**, propuesto por Google, y popularizado por el proyecto Hadoop (*framework* más popular para realizar analítica en *Big Data*). A través del uso de funciones muy simples y sencillas (basadas en las primitivas de Lisp), la idea de este modelo de programación es combinar operaciones “map” y “reduce”, cuya implementación está a cargo de los usuarios, y ejecutarlas en un conjunto de nodos de un cluster, cada uno con datos diferentes. El *framework* Hadoop se encarga de dividir los datos en pequeños *pedazos*, designados como pares clave/valor, los almacena en diferentes nodos de cómputo e invoca las tareas “map” para que ejecuten la función definida por el usuario (UDF por *User-Defined Function*); las tareas “map” generan

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pares clave/valor intermedios de acuerdo a la UDF. Subsecuentemente, se inicia la fase "ordenar-mezclar" para combinar todos los valores intermedios relacionados con la misma clave y canalizar los datos hacia las tareas "reduce" que se ejecutan también en paralelo y que realizan una agregación de los resultados; las tareas "reduce" son aplicadas al conjunto de datos con clave común de los pares clave/valor generados por "map" y producen el resultado final. Todo este proceso es representado como un grafo acíclico dirigido (DAG por *Directed Acyclic Graph*), donde los arcos representan el flujo de pares clave/valor y los vértices son las operaciones "map", "ordenar-mezclar" y "reduce". MapReduce ha inspirado otros modelos de programación que lo extienden agregando características particulares para aplicaciones específicas, tales como PACT (*Parallelization Contracts*) y Spark.

PACT extiende el modelo MapReduce con contratos de paralelización, representados en el DAG. Los arcos en el DAG representan canales de comunicación que transfieren datos entre diferentes subprogramas. Los vértices representan los programas que reciben los datos de los canales de entrada, los procesan y producen los resultados en los canales de salida. Comparado con MapReduce, PACT ofrece funciones adicionales a "map" y "reduce", que permiten definir tareas de procesamiento de datos más complejas, que a su vez representan distintas estrategias de paralelización. **Spark** propone un modelo de programación que en lugar de usar DAGs, como MapReduce y PACT, se enfoca en aplicaciones que reusan un conjunto de datos de trabajo a través de múltiples operaciones paralelas. Spark provee dos principales abstracciones: RDDs (*Resilient Distributed Datasets*) y operaciones paralelas sobre estos datos. El RDD es una colección de datos de sólo lectura, particionada a través de los nodos del cluster y mantenidas en memoria principal, así pueden ser usadas por múltiples operaciones al estilo MapReduce. La capacidad de Spark de realizar las operaciones en memoria –a diferencia de MapReduce y PACT que las ejecutan en disco–, le otorga la característica de alto desempeño. Así, es muy común el uso de Spark para procesamiento analítico de *data streaming*, en aplicaciones de análisis automático y en tiempo real de videos o datos de medios sociales. En general, el sistema que implementa el modelo de programación (como Hadoop para MapReduce y Nephele para PACT), es el encargado de manejar la planificación automática, la tolerancia a fallas y el balanceo de carga sin intervención del usuario.

Estas distintas expresiones de MapReduce se están usando actualmente en ámbitos de motores de búsqueda y medios sociales (Google, Yahoo!, Facebook) para, por ejemplo, construcción de índices para búsquedas, agrupación de noticias, optimización de publicidad, detección de Spams; así como en ámbitos científicos para análisis de conflictos en Wikipedia, procesamiento de lenguaje natural, bioinformática, análisis de partículas, análisis de cadenas de proteínas, simulación de clima oceánico, y mantenimiento predictivo de aviones.

La esperanza como científicos, profesionales e investigadores en esta área es que estas herramientas se sigan desarrollando para su buen uso, como lo ha sido la programación paralela clásica que ha permitido grandes avances en la ciencia y en la tecnología, más que usarlas para fines poco altruistas. Las potencialidades de estos nuevos paradigmas proveen de capacidades sin precedentes, no sólo como una bola de cristal para promover el consumismo o manipular las opiniones de los usuarios (recordemos los escándalos de Facebook en manipulación de datos privados), sino para el bienestar de la humanidad y mejorar el mundo.

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Revista Venezolana de Computación

ReVeCom (Revista Venezolana de Computación) es la primera revista venezolana arbitrada, periódica, digital, orienta a la publicación de resultados de investigación en el campo de la computación. ReVeCom fue creada por la SVC (Sociedad Venezolana de Computación) y tiene entre sus objetivos hacer conocer los trabajos de alta calidad investigativa que se realizan a nivel nacional, latinoamericano e internacional. La revista permite la divulgación de artículos con aporte original en castellano o inglés.

ReVeCom es una revista abierta para una mayor difusión de los resultados de investigación. Cuenta con una página web (http://www.svc.net.ve/revecom), donde se encuentran los trabajos publicados e información sobre la revista. La revista promueve la pluralidad de intereses, dando cabida a la divulgación de trabajos de todos los campos del conocimiento inherentes a la computación.

Este volumen de ReVeCom (Vol. 5, No. 1) corresponde a artículos de investigación en el campo de la computación que fueron seleccionados a través de un riguroso arbitraje por expertos del área. En esta oportunidad, el comité evaluador fue compuesto por:

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Towards the Development of a Platform for Children Virtual Books based on Augmented Reality

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Abstract: In the current world, people can both support and improve their skills using new technologies. Particularly, the reading process could be enriching employing virtual reality features, adding educative virtual content in books. A virtual book is composed by 2D/3D content superimposes over a physical printed book, focus into obtain a new perspective of the classical reading process. Then, if this perspective can be added from the early stages of reading process, it could improve that process. Most tools to create these books are associated with a specific domain and development (e.g. editorial-based formats and conditions, according to the kind of book), and they are not free to access. We present a robust and efficient platform to develop interactive books using augmented reality, mainly we focus on children books. The platform is web-based offering a simple and dynamic platform for writers and final users. This is capable to create, distribute, and manage books in a customized way, adding resources such images, sounds and videos. We evaluated our proposal in 20 people measuring the time to complete a virtual book in the created platform, moreover, we achieved a questioner to obtain how difficult the process is. Results allow identifying the advantage and disadvantage for users, validating our approach obtaining satisfactory results. We are focused on continuing the expansion of the virtual book development process, which might be a new expansion research field in our country.

Keywords: Virtual Reality; Augmented Reality; Virtual Books; Reading Process; Web Platform.

I. Introduction

The reading process is an important habit to obtain mental benefits in humans. This helps in the cognitive process, improving our expression capability, increasing our vocabulary, and eases the learning process itself. Reading readiness starts in childhood supported for the Elementary School in different regions around the world. Nevertheless, this process is just the beginning of a consequent habit. The interest in children to read books as a pleasure, above a duty, is considered a real challenge.

There are technological solutions which support the teaching process since early ages. Mainly, these are formed with images, texts, positive feedback and sounds. For instance, the usage of interactive applications to immerse children into books is one to remark, called the augmented reality. Augmented reality (AR) is a technology which adds a new perception and interaction with the real world, allowing users the sensation of a real environment taking additional information from a computer device [1]. This opens a new way to see virtual elements on the real world, letting a new way in human perception. There is evidence that current technologies play a crucial role in modern education models.

According to Azuma [2], the AR is a variation of the Virtual Reality where the user can see the real world around him, supplementing the reality superimposing virtual objects with the real world. Also, Azuma defines three characteristics for each AR system: 1) combines real and virtual, 2) interactive in real time, and 3) registered in 3D. Those characteristics are the basis for different applications in different areas: medical, visualization, maintenance and repair, robot, annotation, education, robot path planning, entertainment, and military aircraft navigation and targeting.

Studies of Furht [3] shown a classification of augmented reality systems based on the mobility of users and systems such as: fixed indoor, fixed outdoor, mobile indoor, mobile outdoor and mobile indoor/outdoor systems. The selection of the type of system is a crucial decision before starting to develop an augmented reality application.

This relation between education and technology is one of the most concerning problems in different research centers which study this field [4]. Focusing in the construction of a reading habit, a few studies have been investigated on that as a systematic way to learn. A complete classification of augmented reality books is presented by Altnpulluk and Kesim

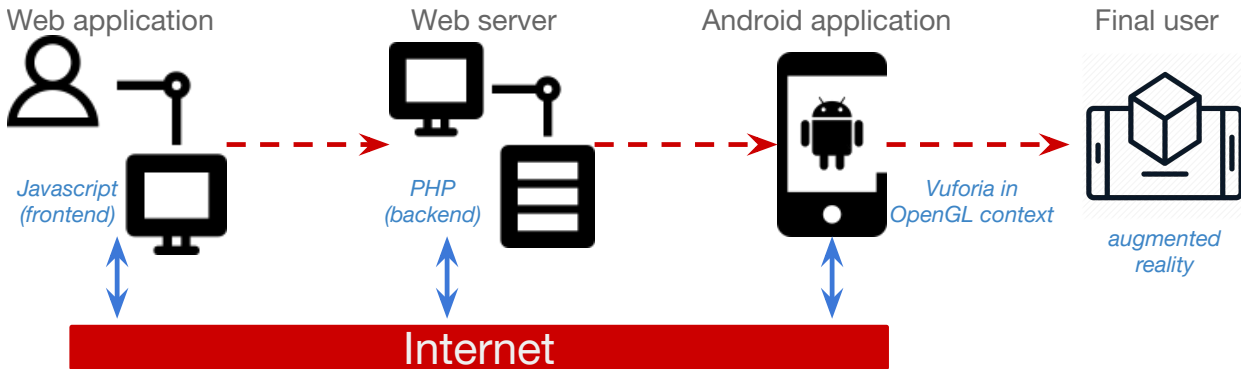


Figure 1: Overview of Proposed Architecture with its Components. Pipeline is Presented from Left to Right

[5], which is an excellent guide to explore more in depth this topic. This paper argues the developing of a platform to develop virtual books for children, defined as interactive books which offer a new experience from the traditional reading process. The virtual book approach is built with augmented reality to make a novelty solution for writers (i.e. authors) and final users (i.e. children). Thus, final users can visualize and manipulate virtual objects over physical book's pages. According to our knowledge, in Venezuela, this is the first research which explores this kind of approach.

Basically, our solution is composed of two main components: a web platform and a phone-based application. The solution provides to authors a robust and friendly tool to develop interactive books, and it provides to children some activities such as watch, select, download and play books with AR using an android-running device (i.e. tablet, smartphone). The available content for books is easily inserted using the web platform. The reader should bear in mind, that this study is based on children with the capability to manage smartphone devices and with the reading readiness initiated.

First, in Section II, the paper outlines a brief overview of existing solutions in literature for virtual books using augmented reality. Next, in Sections III and IV, we introduce our approach to assess our contribution to creating virtual books, explaining in detail each developed component. Following, Section VI shows the evaluation of our solution both qualitatively and quantitatively to test its impact. Finally, conclusions and future work are presented in Section VII.

II. Related Work

The study of Dünser and Hornecker [6] examined how the young children interact with augmented reality storybooks. The study shows different behaviors according to the integration of interactive sequences using AR technologies. Also, their observations demonstrated that most children were able to interact with the system without much prompting.

Magic Book, developed by Billinghurst et al. [7], might be considered as the first successful attempt to create books using augmented reality. With Magic Book, users are able to read the text in a traditional way mixed with AR elements. The pages are enhanced, showing a 3D content using a traditional PC. Nowadays, this approach is replacing by the usage of massive mobile devices such as tablets or smartphones.

Some authors have considered the study and development of children virtual books using mobile devices whether to show 2D/3D content [8][9][10], being part of classroom activities [11][12], or other interesting topics [13][14]. Likewise, some studies are focus on the semantics of mixed reality books, and in the graphical design space user experiences [15]. Most researches use a mobile device to give the flexibility and availability in multiple environments. Indeed, there are approaches which use additional specialized hardware such as head mounted display [16] or a kind of specialized paper [17].

Recently, some noteworthy solutions were presented: Children's Literature [18] and Coloring Book [19]. The first explains, in a simple way, the Bible story adding music, animations, voice, and storytelling. The second one is an application to draw 3D designs with hands-free interaction, getting a high-level of the artistic expressions from users. Also, in 2016 Laine et al. [20] presented a game-based book and storytelling as methods to generate intrinsic motivation in learning.

On the other hand, exploring the commercial companies, they exploit this new tends on technologies using mobile devices to create virtual books. An instance, the company Carlton Publishing Group[1] which sales a collection of books that include augmented reality sequences on each book. Its approach is based on the usage of a mobile application available to download. An outstanding application of this kind is called ZooBurst[2], which is distinct as a digital storytelling tool to create 3D pop-up books using iOS devices. Another alternative of this kind is Augment[3], an application which works on both Android and iOS operating systems getting a set of tools to construct different applications, using augmented reality.

Overall, there seems to be some evidence to indicate the rich experience stimulates the human senses. It allows a comfortable interaction user-content in reading, hearing and displaying static images or 3D models through AR, thus

[1]https://carltonbooks.co.uk
[2]https://zooburst.com
[3]https://augment.com

enhancing the learning process. Despite of existing options, they require a medium-to-complex setup, or to buy a usage license, or is only available for joined authors in a particular publishing company.

Using all these previous works, we are motivated to create an open and free platform for the creation of virtual books without a dependency or restrictions of commercial companies. Also, we try to integrate usability aspects to enhance the user experience, even for writers and final users.

III. Approach

A visual overview of the proposed approach is presented in Figure 1. We decided to use in our investigation the mobile indoor and outdoor approach [3]. Our solution offers the development of a virtual book using a web platform and an Android application to interact with the augmented reality elements. The virtual book is represented as a printed book with markers, displaying the AR when the device's camera is pointing to markers into the physical book. Figure 2 shows an example of how it looks in a real scenario.

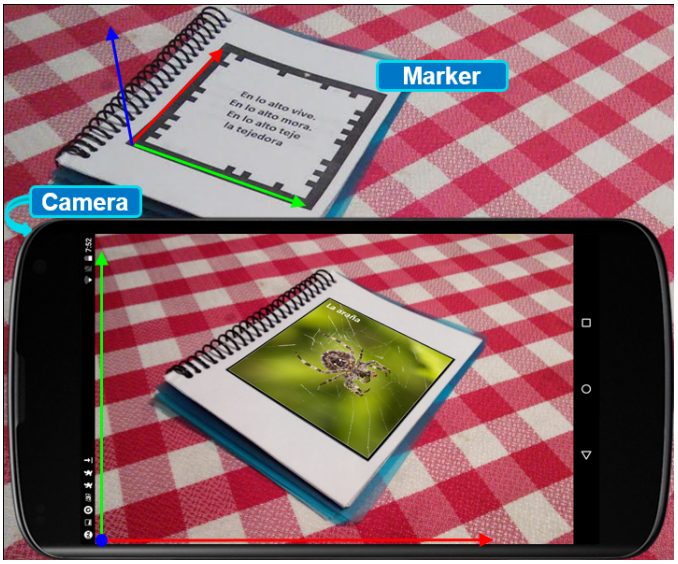


Figure 2: Example of our Approach Displaying an AR Element over a Physical Book

The pipeline process (see Figure 1) starts with a web application running into a web server, that can be access from a web page or from an Android application. The application allows an entire mechanism to build, store and publish virtual books. Similarly, a web server and database are provided to manage the permanent storage and the web services. Both modules (web application + web server) are grouped in a web platform, explained in detail in Section IV. Then, this platform allows the creation, composition and posterior download of virtual books.

When a virtual book is downloaded, it contains the references for each placed element such as text, images, sounds and videos encoded as markers. Each marker can be read using the mobile device application, to reproduce the AR element. Once the virtual book is printed into a regular paper (i.e. physical white paper), the Android application is used to connect it directly to the web server, and to obtain the AR elements and correspondingly reproduce them. Notice that all mentioned modules require connection to Internet.

Lastly, a final user can visualize the AR elements over the physical book, and the user can interact with that elements. For instance, the user can show/hide elements, or reproduce several times a video.

IV. Web Platform

A web platform is designed using tools to create new virtual reality complements. These complements were incorporated in the virtual book platform. Basically, this platform is composed for a front-end and a back-end module (i.e. a classic web platform). Specifically, we used the following technologies:

- Front-end: JQuery[4], JavaScript programming language and Bootstrap[5]
- Back-end: PHP programming language, ZipStream-PHP[6], MySQL[7], Apache and Google Chart Tools: infographics[8]

Likewise, the internal architecture of the web server is composed of different layers: Request Manager, Logic, Data, and View layer. The Request Manager layer analyses the HTTP requests and invokes the core-algorithms (i.e. the functional workflow) to be applied; this layer is connected with the font-end. The logic layer contains all transactional algorithms to interact both Data and View layers. The View layer generates the HTML content to be shown to the users (i.e. front-end). Finally, the Data layer manages the persistent data and multimedia resources. The Data layer has direct access to the database; however, it could change according to certain data protection policies.

Given the nature of the functionality-based structure of our solution, where several layers are involved in a single fully-functionality process, we produced tasks that have to be accomplish by the web platform instead of associated tasks on each layer. This division allows us not to enter in depth technical details of our development (in the domain of this article). For instance, the following tasks are implemented:

- Selection and visualization of multimedia content: It allows to the users to select the multimedia content to be stored in the platform. This content should be available to incorporate them into virtual books according the user permissions, as limited or full access to all available resources in the server.
- Incorporation of new multimedia content: It allows to users the capacity to add their own multimedia contents, and specify their visibility for public or private content. In this context, public means available to all users in platform, and private that is only available for its owner.

[4]https://jquery.com (Javascript library)
[5]https://getbootstrap.com (HTML/JS/CSS library)
[6]https://github.com/maennchen/ZipStream-PHP (Streaming library)
[7]https://mysql.com (Database manager)
[8]https://developers.google.com/chart (Web-based visualization library)

Figure 3 shows an example in how the available content is presented to the writers in the platform.

Figure 3: Example of Available Content for Writers in the Web Platform

- Edition of pages: It offers to the users a set of options to add into a page of a virtual book.
- Storing data: It efficiently stores the data to access by a user in any request. The web platform uses thumbnails to present the content.
- Adding description: The users are able to add a short text description of a book, also to add a cover image to identify it on future requests (e.g. a thumbnail image).
- Generation of fiducial markers: It offers to the users the option to mark an image as a fiducial marker. Generally, the fiducial marker should be a special symbol: QR code, geometrical filled polygon, or others. The solution provides the option to use images, being markers recognized by the Android application.

In our context, a fiducial marker is defined as an object or image placed on top of another image or region of interest. It is used as a reference point to identify a spatial location, a measure or a feature in a page of a virtual book (i.e. spatial layout location). A fiducial might be a simple coin with well-known dimensions, or a metric rule used to calibrate some dimensions on captured images.

The web platform besides offers basics functionalities presented majority of the web-based systems: the CRUD operations (Create, Read, Update and Delete) of data stored in relational databases. Therefore, validations of data input and user control are components of the proposed web platform. Once all elements of the web platform are setup, we focus on the creation process of a book by the writers.

A. Book Management

The first step for the writer user in the web platform consists in the creation of the book. This process requires adding required information to get a proper books profile in the platform. As part of these information, is noticeable the following:

- Title: specifies the title of the book.
- Author(s): indicates the main author(s) of the book.
- Synopsis: conveys a full narrative of the book.
- Cover: identifies the book cover image.

The introduced information is received for the front-end module, and the back-end module processed the data to validate the inputs in some cases such bad image formatting, existing book's title, and any kind of validations. Each book maintains one of two possible conditions: "in construction" or "finished". The default condition for books is "in construction', until the writer decides to finish the creation of the book, changing of status.

Using the web interface, the users can visualize the existing books created by themselves, screening relevant information such as date of creation, status, and size in megabytes. Next, it is likely to add multimedia content to the already created books. This process is explained in detail in Section IV-B.

The last step after completing a book creation process is the publishing stage. To publish a book, all the content must have a maximum of 100 to 150 MB, mainly for the limitations in the network (i.e. low and mid-range internet speeds). It is clear that the multimedia content is stored in the server, and the Androids application have to download that content join with the definition of fiducial markers. For example, if a book contains seven fiducial markers corresponding to seven multimedia contents of 100 MB each one, then the application must download 700 MB, only for the first usage. The proper balance of the multimedia data is relevant to the constructions of virtual books. However, that limitation on size in bytes, could be change according to our storage device capacity and the networking capabilities.

The publishing process output consists of a single file. This file contains all items mentioned in Table I. The file might be download using the mobile application and stores in the device memory.

Table I: File Content to be Installed in the Mobile Device

Content	Description
Fiducial Marker	Multimedia content interpreted to be executed as AR
QR code	Identification of each book in the system
Readme file	User instructions to incorporate AR into physical book

When a book is marked as "finished", the publishing process, which runs in the server, sends a notification to all users which have that virtual book installed in their mobile devices. For instance, this notification appears for users as shown in Figure 4.

Each book created in the platform must have been a unique identification instead of using classical id correlative numbers. We used QR codes (Quick Response Code) which can be read using the camera of the mobile. In this way, it is possible to determine which is the book to download from the web server. A simple QR is a trademark based on a 2D barcode, which is encoded to store data efficiently.

B. Multimedia Content

The main goal in the book creation process is the addition of multimedia content to virtual books. When a multimedia

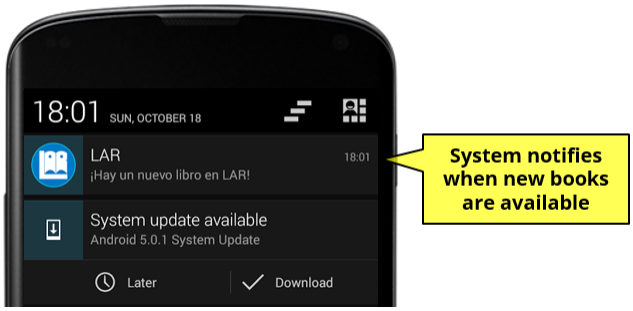


Figure 4: Notification Message when a New Content is Available to Download

content is added into a book, a fiducial marker is linked with an image, sound or video. This content is chosen from a predefined list of resources, or can be inserted as new content. To add a new content, it is necessary the following information:

- Description: It adds a short description of the content. This field works as a reference in the available list of resources presented to users.
- Permission: It identifies the kind of usage permission of content. (e.g. rights managed, royalty free, public or private)
- Error message: In case of any error when the content is downloaded, it allows shows a personalized message written by the author.

In order to standardize the content, we decided to use PNG and JPG formats for the images; MP3 format for the sounds; and MP4 for the videos. Indeed, we strongly recommended that each file cannot be larger than 75 MB. For other side, to maintain a good quality on the server side, the server executes auto-maintenance functions. When certain content does not belong to any finished book, and it has more than 4 weeks on the server, then that content is removed. This policy is applied for storage limitations in low-end servers.

V. Android Application

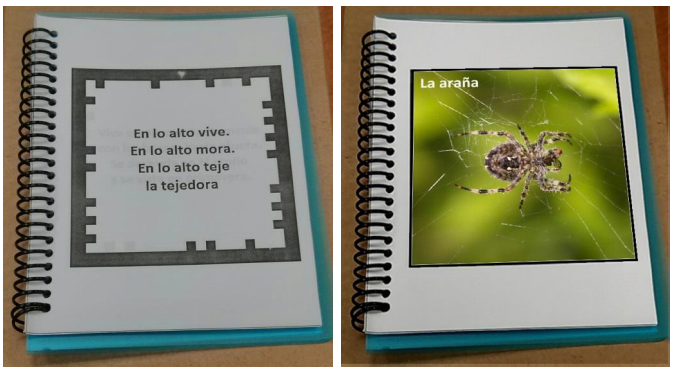
Currently, several libraries and SDKs have been developed to include augmented reality into software applications. Noteworthy examples are Zappar[9], ARToolkit[10], DroidAR[11], Blippar[12], Layar[13], Metaio[14], NyARToolkit[15], and Vuforia[16]. It is might being clear that there are a few more, but those are a subset focus only in mobile applications development. After tested the advantages and disadvantages of each one, we chose Vuforia. This selection was followed after the evaluation of aspects such markers detection, QR decoding, licensing, ability to play music, video, and audio.

[9]https://www.zappar.com (AR solution)
[10]http://www.artoolkitx.org (AR library)
[11]https://bitstars.github.io/droidar (AR framework)
[12]https://www.blippar.com (AR solution)
[13]https://www.layar.com (AR solution)
[14]https://metavision.com (AR solution)
[15]https://github.com/nyatla/NyARToolkit-for-Processing (AR library)
[16]https://developer.vuforia.com (AR framework)

Vuforia does not force the usage of a watermark in the screen (as other solutions do). Also, it can be used with a free license excepting the image recognize cloud feature (which is not included in this work). Additionally, a very important matter to consider using Vuforia in our project is the documentation for developers, which is free to access and contains several examples. For the technical point of view, we integrated other libraries in our proposal. For example, the Zbar library, available in http://zbar.sourceforge.net, is used to recognize effectively the QR codes, and the SQLite database manager to store the data locally.

The Android application is the component of the system which interacts directly with the destination user (i.e. children). This application contains a set of basic functionalities in a lightweight application stored in the mobile device. These functionalities are summarized as follow:

- Marker recognition: It finds into the captured image a known pattern to reproduce its associated multimedia content.
- Content reproduction: It reproduces through the output device (e.g. mobile screen or mobile speakers) the content using the augmented reality technology. For example, the Figure 5 shows a printed riddle surrounded by a marker using the mobile device camera, where the answer is presented an image and text (i.e. spider).



(a) A simple riddle (b) Image showing the answer

Figure 5: Reproduction Example of the Content using the Android Application

- Extraction and data management: It consumes web services available to users, which is available as augmented reality add-ons. This allows selects which feature will be used to store in the internal memory of mobile device. Then, once is stored in local memory, there is no necessary the Internet connection to transfer the content.
- QR decode: It decodes the QR code and does the communication with the web platform to download the data for a specific book.
- Add-ons administration: It allows managing the augmented reality add-ons which are store locally. Also, users can manage the add-ons available on the server to be download to their devices. Notice that this process is performed under request of users.

The Android application was designed using the Model-View-Controller pattern, to construct the user interface. A part of the graphical user interface is shown in the Figure 6. The proposal design considers the web server where is hosted the web application and the centralized database.

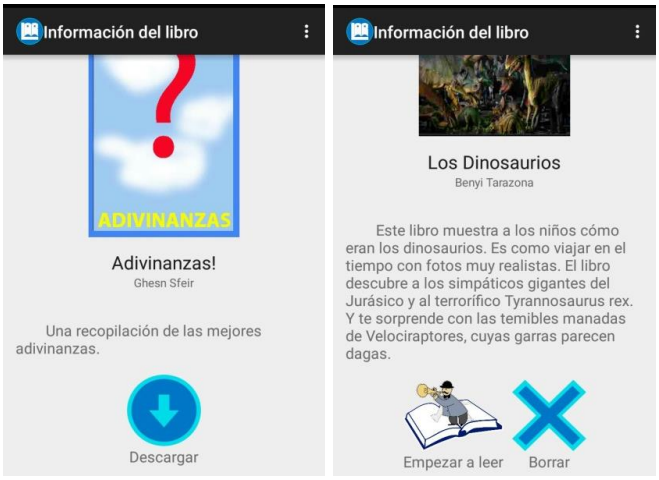


Figure 6: Examples of the Graphical User Interface in Mobile Devices

From the technical perspective, this approach allows an easy switch for the native code developed to reproduce images, videos and sounds indistinctly in a captured image. The multimedia content in virtual books complements the existing information, without discarding the importance of the written content in the physical paper.

A. Augmented Reality

When the content is rendered in the screen of a mobile device, the application should setup a scenario. This is not always applied owing to augmented reality setup consumes resources in processing. First, the initial environment is created once the camera turns on. This environment consists of the creation of an OpenGL context, after, a list of available contents in the server is loaded. This loading process is completed asynchronously showing a logo during this process (e.g. a visual way to wait for the loading).

Next, the recognition process of marker location is done using image processing algorithms. For instance, an image mask is created where a low-pass filter, thresholding, and the Harris corner detector are executed (in the mentioned order) to obtain the location of the marker. These algorithms work assuming a good lighting conditions at the moment of capture.

Finally, the location of the multimedia content is calculated, projecting a 3D plane over the found markers, and re-project onto the screen 2D to obtain the output location in device's coordinates. The center of these coordinates is found projecting the content, which might be a reliable solution for our proposal. Figure 7 shows an example of the video location in the mobile device screen.

Figure 7: Reproduction of a Video once a Marker is Detected

VI. Experimentation

1) Virtual Books: A case-study was chosen to evaluate the effectiveness of our proposal. We built a total of 22 virtual books changing the number of pages, number of images, number of videos, number of audio and size on each one. The behavior of our application is analogous in all cases, getting similar results. For instance, if all resources have the same size, the construction of a virtual book with five multimedia resources consumes X MB, and a virtual book with ten resources consumes $2 \times X$ MB approximately. There is no a considerable payload of data excepting by the multimedia data. If the same resource is selected twice, then that resource is only store once.

A sample case of a virtual book created can be appreciated in Figure 8, where 4 pages are displayed. From left to right, markers represent an image, a video (both enclose into a square) and two sounds (eighth note encloses into a square). For instance, that virtual book was printed in bookbinding to be used by children.

2) Construction Time: We performed a test to measure the construction time of a book. Then, we set up a population of 20 users to create two different books. The ages of the users are between 20 and 35 years. On average, the time to develop the first book was 31.5 minutes; and for the second book were 27.75 minutes. Despite the time, two users could build a ten-pages book in a time less than 15 minutes.

To be more precise, the number of pages constructed by test users were between eight and ten pages. This requirement was settled by authors, to obtain a more precise measurement and avoiding a difference for the number of pages. Also, only the 50 % of resources were available on the server. Users must download part of the content from the Internet, simulating the real book construction process.

3) Construction Process: After a little survey at the same population (i.e. 20 people), we carry out the following question:
How do you consider the complexity in the construction of the book using the Web platform?

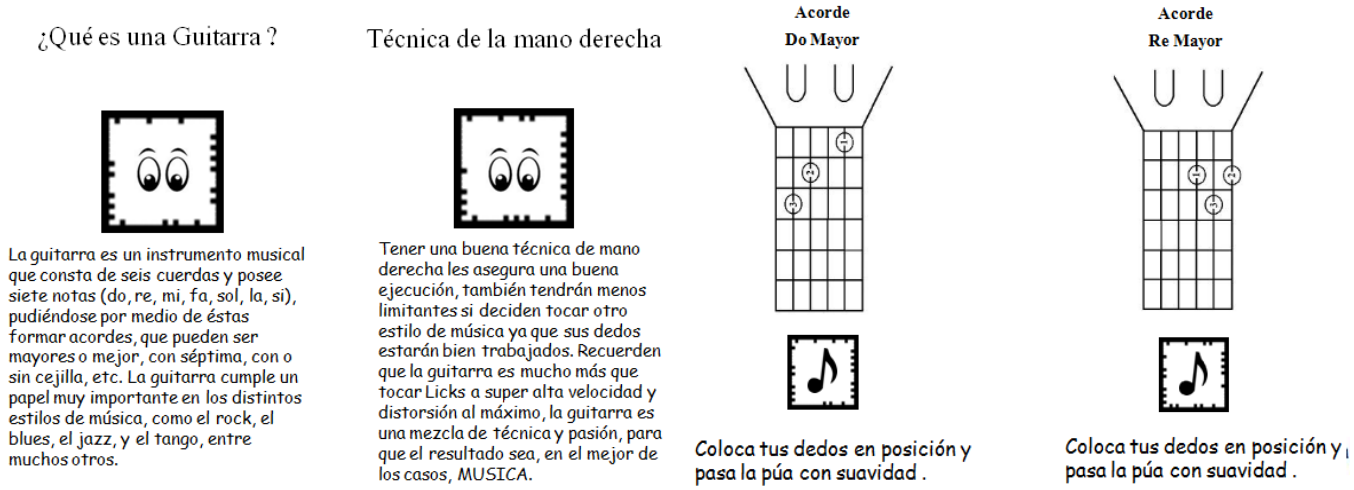


Figure 8: Example of four Pages of the Virtual Book titled "Mi Guitarra y Yo"

The results are shown in Table II, where answers were classified from very easy to very complex (five options).

Table II: Answers Concerning Complexity of a Book

Options	% of answers
Very complex	0
Complex	10
Regular	20
Easy	25
Very easy	45

Results show that users do not consider a **very complex** process the web platform (10%). The 45% answered that process was **very easy**, and other 45% consider the process as **easy-regular**. Importantly, most of the users have a knowledge about filling forms online, with the capacity to write and continue a guided process in web pages. Separately of the age range or abilities to handle online forms, could be very useful have some kind of measurement tools in order to balance the results according the capacities of users before start the process.

In order to continue exploring the users' capacity, we fulfilled another question in the same group:
How difficult is to incorporate markers into books?.

Using the same scale previously defined (very complex to very easy), results show that 15% answered Complex, 40% Regular, 15 % Easy and 30% Very easy. Thus, the multimedia content would be placed in a specific location, with a precise size and resolution (for images), to get a good visual result in the final printed book. For this, the users take more time adding this content. We believe that knowledge in visual design or aesthetic to diagram content is a plus for this process, reducing the construction time.

4) Survey: For this test, we performed three questions to evaluate the final result. These questions were made thinking in final users, the children, considering their ability to read and handle mobile devices. Table III shows the pair question/answer presented to 10 children with 6 to 11 years old. The possible answers are Yes/Not, being short and easy to answer.

Table III: Results of Questions Asked to Children

Question	Yes	Not
Do you like it?	9	1
Is it new to you?	10	0
Do you want see more?	9	1

The most remarkable aspect is concerning the novelty of the application. In spite of aforementioned aspect in Section II, there are applications of this kind. However, those are widespread applications such as games, camera-related or social-media networks. In any case, the positive impact surveyed is noticeable. Again, we have to remark that these results are into our test domain and clearly do not represent a widespread population where other aspects should be considered (exposition time to electronic devices, social environment, among others).

An important not-measurable aspect, at least for this research, was the notorious surprise and emotion of children. In all cases, they show positive feedback in all books presented to them. Figure 9 shows one of the surveyed, Jade a 7-years old girl, playing with one developed virtual book.

5) Considerations: When the mobile application is running, there are some external factors to consider: lighting conditions, camera quality and distance from camera to marker. A strong incident light over the marker on the physical paper will not allow the proper detection by the algorithms. This aspect, joining with the quality of the camera, allows an appropriate image to be processed. In this research, we captured an image on each frame, after the image is pre-processed to determine if the captured image is valid to be consider as a marker. Our tests show that when the resolution of the camera is less than

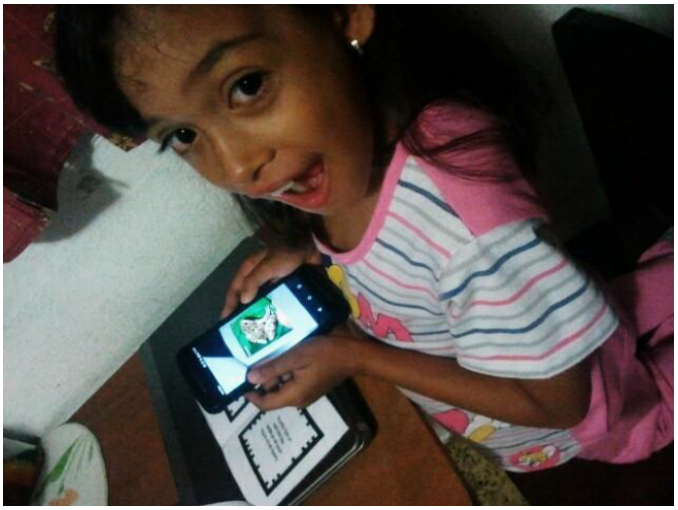


Figure 9: Usage Example of the Application. Photography Conceded with the Authorization of *Mr. Bocanegra*, Jade's Father

3 MP, there are false positive in corner's detection around of 40% cases, tested 50 times with 4 different devices. In this study, we are only considering the megapixel count, however there are other aspects that strongly impact into a good quality of images such as sensor size, pixel size or focal length.

Finally, the distance of the device to the printed physical paper is relevant. Also, the quality of the camera affects directly this feature. Bigger distances (between 30 cm and 80 cm) are captured very well using good pixel resolutions of cameras (i.e. 5 MP and above). However, this distance is not acceptable in lower pixel camera resolutions. To reach the expected results, we strongly recommend a distance between the focus of the camera (around 5-15 cm) until 25 cm for all cases.

VII. Conclusion and Future Work

This research was undertaken the design and development of a solution to create virtual books for children using augmented reality which pop-up image, video, and audio over the physical printed books using a mobile device. The solution includes an available web platform for writers and, an Android application for final users. Final users are children, which in our test, always demonstrate to be surprised by presenting visual results in devices.

Our solution presents high flexibility to writers designing books. Thus, virtual books are benefiting from the creativity that writers added to them. This offers a huge variety of styles to reproduce the augmented reality elements. Similarly, the fact to add their own content to increase the mentioned flexibility. There is no limitation to the final goal of the books: educational, entertainment, recreational, and other book genders.

There is no doubt about the impact of the augmented reality in bringing to the real-world multimedia content, enriching the read experience. Particularly, modern children find new ways to learn using the new technologies. The virtual books are an outstanding demonstration in how the new technologies can improve our habits. Moreover, we think that might be endless ideas and possibilities using AR.

It is important to remark that we assume a permanent connection to Internet. All multimedia content must be downloaded at least the first time, from the web server. This might be inconvenient due to the size of the content and the response time to show them, which depends on the networking platform. Also, it can be affected when limited mobile devices are used. In a near future, it would be a good approach the designing of a full desktop application for more advanced users, or offer a more complex options for advanced users too.

Therefore, a definite need for visualizing 3D content on the virtual books is a challenge. This can be reached allowing the loading and displaying of this content on the web platform and the mobile application. Also, now the application is limited to Android-based devices, being iOS devices a big market alternative. Further, in the near future, we plan to create books to support our previous researches focus on educating children [21][22] in particular goals. At the same time, it is possible to compare our solution with other platforms/libraries and determine the differences, focus into take advantage of the final product.

Emphasis on the impact of our solution, we only measured the technological and perception aspects from children. It is very important count with a study in the correlation between the usage of the solution with the time to measure a learning progress. This should be done to determine an expected positive result, increasing the learning curve. However, this topic is out of our knowledge and could be running by psychologists and children educators.

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MIHH: Un Modelo de Interacción Humano-Humano

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Resumen: La interacción entre personas es un proceso necesario para la convivencia en sociedad. La comprensión de ese proceso es fundamental como base para describir, explicar y reproducir interacciones que involucren personas, tales como, la interacción con máquinas. Los modelos encontrados en la literatura sobre la Interacción Humano-Humano, carecen de elementos característicos, que influyen en los procesos de interacción, como los estados afectivos y el inconsciente. En aras de obtener un modelo basado en las características de la comunicación entre humanos para construir modelos de Interacción Humano-Robot, en este trabajo se hace una revisión de la literatura sobre los modelos más relevantes de comunicación entre humanos, y además, se estudian los aspectos particulares de la comunicación humana. A partir de allí, se propone un Modelo de Interacción Humano-Humano (MIHH), basado en 14 premisas que fueron extraídas de la literatura consultada y comprobadas experimentalmente.

Palabras Clave: Modelo de Comunicación; Modelo de Interacción; Interacción entre Personas.

Abstract: Interaction between people is a necessary process for the coexistence in society. The understanding of this process is fundamental as a basis to describe, explain and reproduce interactions that involve people, such as the interaction with machines. Models found in the literature about Human-Human Interaction, lack of characteristics of this process in people, influencing in the processes interaction, like the affective states and the unconscious. In order to obtain a model based on the communication characteristics of human-to-human to build models of Human-Robot Interaction, this paper reviews the literature on the most relevant models of human-to-human communication, and also studies the particular aspects of human communication. From there, it is proposed a Human-Human Interaction Model (MIHH), based on 14 premises that were extracted of the literature and tested experimentally.

Keywords: Communication Model; Interaction Model; People Interaction.

I. Introducción

La interacción entre humanos puede ser descrita por modelos que representan los diferentes aspectos involucrados en todo proceso de comunicación; sin embargo, en cada ámbito comunicacional, hay elementos propios o particulares. Por ejemplo, según [1], en los seres vivos, el lenguaje es exclusivo de los humanos. Hay autores que se refieren a los seres humanos como animales sociales [2], incluso en la Antigua Grecia, Aristóteles hablaba del hombre como animal social [3]. Otros autores se refieren al hombre como un ser gregario, es decir, que requiere de la interacción con sus semejantes para su existencia [1]. Los seres humanos se agrupan en sociedades, siendo para algunos autores [4], la comunicación, la base de la vida social.

La comunicación interpersonal es la modalidad comunicativa más frecuente en las interacciones sociales; de hecho, [5] menciona que durante la mayor parte del tiempo los humanos están en interacción con los demás. Según [6], a pesar de que el abordaje de la comunicación interpersonal desde las ciencias sociales ha sido tradicionalmente considerado con una gran sencillez, es una forma de comunicación extremadamente compleja, en la que se encuentran una multitud de elementos que interactúan [5]. Es tan importante, que quienes están limitados en su uso, presentan serios problemas en la relación social y en el desarrollo de sus potencialidades, como es el caso de los que padecen limitaciones sensoriales (sordos, ciegos, etc.), condiciones mentales (autismo, depresión, psicosis, etc.) [7], entre otros.

Las interacciones entre personas pueden realizarse en ámbitos organizacionales o personales, pueden ser formales o informales, estrechas o distantes, antagónicas o cooperativas, y colectivas o individuales [8]. El interés por hacer una nueva revisión de la interacción entre personas está fundamentado en dos premisas: primero, la carencia de elementos propios del ser humano en los modelos consultados en la literatura, en concordancia con lo expuesto por [7], donde menciona que la mayoría de los modelos analizados pertenecientes al siglo XX sugieren una secuencia lineal, estática o bidireccional, de componentes fijos y rígidos; y segundo, la tendencia de incluir aspectos de la interacción humana en las máquinas, en concordancia con [9], que resalta la necesidad de incorporar

rostros a las máquinas que interactúan con personas, con [10], que enfatiza la necesidad de incorporar emociones a las máquinas para determinar sus comportamientos, y con [11][12], que muestran la importancia del reconocimiento de emociones en las personas por parte de las máquinas.

En ese sentido, en este trabajo se propone un Modelo de Interacción Humano-Humano (MIHH) basado en los aspectos particulares de la comunicación humana, considerando en particular, aspectos tales como, los estados afectivos y el inconsciente. MIHH fue diseñado según 14 premisas que fueron extraídas de la literatura consultada, y comprobadas experimentalmente en esta investigación. El objetivo de este modelo es que pueda ser usado en trabajos futuros, para construir modelos de Interacción Humano-Robot.

II. Antecedentes

Por el propósito de este trabajo, en los antecedentes solamente interesan los trabajos que han propuesto formas de Interacción Humano-Humano. El primer indicio de esquemas que explican o describen la interacción entre personas se remonta a la Antigua Grecia. Según [13], el modelo aristotélico de la retórica propone que todo discurso está compuesto por tres partes: el orador, el discurso y el oyente. Éste es un modelo elemental, que hace referencia a la persona que pronuncia las palabras, a la estructuración de las palabras, y a la persona que escucha.

En la segunda mitad del siglo XX se desarrollan varios modelos de comunicación sobre la interacción entre personas. En ese sentido, en [14] se presentan cinco modelos. Por otra parte, en [15] se presentan cuatro modelos más. A finales del siglo XX, en [7] se presenta el modelo psicológico explicativo de la comunicación interpersonal de Casado, pensado para la comunicación interpersonal cara a cara, que consta de seis fases: i) Fase precomunicacional; ii) Fase de contacto tangencial; iii) Fase inicial propiamente dicha; iv) Fase media o de mantenimiento; v) Fase final o de cierre; vi) Fase postcomunicacional.

A principios del siglo XXI, en [1] se presenta un modelo de comunicación verbal que muestra la relación de los elementos del proceso de comunicación, en un flujo de información oral y escrita. En este modelo, por un lado está la persona que emite el mensaje y hace el papel de fuente y transmisor, y por otro lado está quien lo recibe y lo decodifica. La parte del codificador incluye un módulo de expresión (fonación y escritura), y la parte del decodificador añade un módulo de captación (audición y lectura). Adicionalmente, asocia la elaboración interna a la persona que codifica, y la comprensión a la persona que decodifica. Por otra parte, en [16] se presenta un modelo sinérgico que concibe la comunicación como un proceso transaccional que considera características individuales de las personas (edad, raza, etnia, nacionalidad, género, etc.), aspectos sociales (estructura social, política, económica, histórica, etc.), elementos culturales (patrones, valores y comportamientos compartidos por un grupo de personas) y el contexto (configuración y aspectos del entorno). Finalmente, un estudio que analiza la Interacción Humano-Humano, es presentado en [17], donde modelan el proceso cuando las personas caminan una al lado de la otra, con o sin contacto manual, determinando que sus pasos se sincronizan, analizando la importancia de la interacción háptica en general, y el contacto de la mano entre humanos durante la marcha, incluyendo las fuerzas que surgen de las interacciones físicas.

Adicionalmente, considerando que aunque el modelo de Shannon no es concebido para la comunicación entre personas, también se presenta porque ha sido referencia de varios modelos presentados anteriormente. Según [18], el modelo original de Shannon expone un sistema de comunicación constituido por ocho componentes (fuente de información, transmisor, señal emitida, fuente de ruido, canal, señal recibida, receptor, y destino), cuyo proceso puede ser descrito de la siguiente manera: por un lado, la fuente de información selecciona un mensaje, el transmisor lo codifica y transforma en señal que se envía por el canal, y por otro lado, el receptor la decodifica y transforma en mensaje, que posteriormente llega a su destino.

En general, la mayoría de los modelos de comunicación coinciden en señalar el carácter dinámico del intercambio de información o mensajes, haciendo énfasis en lo que sucede externamente, es decir, lo que se puede observar. Sin embargo, en el proceso de interacción entre personas hay elementos internos propios de cada persona, que intervienen significativamente, tanto en la elaboración o construcción de la información, como en la percepción e interpretación de la misma. Por ejemplo, en la comunicación que involucra personas hay actos que no se estructuran conscientemente, como es el caso de los gestos [19] y los impulsos espontáneos, que surgen bruscamente ante una situación dada [20].

Ahora bien, a partir de los trabajos previos, se puede constatar que hay un conjunto de aspectos que aún no se consideran en un modelo de Interacción Humano-Humano, tales como la posibilidad de romper con esa linealidad y comportamiento estático de sus componentes; o la necesidad de incorporar la influencia de los estados afectivos y del inconsciente, lo cual se intenta cubrir con MIHH (modelo propuesto en este trabajo).

III. Marco Teórico

A. Comunicación Interpersonal

Según [21], la comunicación es un proceso bilateral, un circuito en el que interactúan y se interrelacionan dos o más personas, a través de un conjunto de signos o símbolos convencionales, por ambos conocidos. Según [5], la comunicación interpersonal se podría definir como el proceso de comunicación entre individuos, que tratan de transmitir estímulos a través de símbolos, con la intención de producir cambios en el comportamiento del otro.

Según [22], a la comunicación que se da cara a cara se le denomina comunicación directa. Para [2], en la comunicación directa, la conversación es el mecanismo de interacción, la cual implica una regulación por señales verbales y no verbales, de manera que cada persona hable cuando sea su turno, y se produzcan pocas interrupciones o silencios incómodos y prolongados. También existe la comunicación indirecta, la cual se caracteriza por una distancia espacial, temporal, o espacial-temporal, entre los involucrados; por ejemplo, las palabras impresas, las grabaciones de video, etc. [23].

Ahora bien, la interacción se ve afectada o perturbada por una serie de aspectos que pueden variar, dependiendo de las personas (niños, adultos, ancianos, etc.) y el contexto (educación, entretenimiento, ventas, etc.). Según [1], los

aspectos que afectan la interacción son: semánticos (generados por una falta de coincidencia entre el emisor y el receptor en relación con el significado y sentido que adquieren las palabras, las oraciones, y los símbolos usados), físicos (problemas ambientales que impiden una recepción adecuada del mensaje, como el exceso de ruido o luz), fisiológicos (se presentan en el emisor y el receptor, cuando existe alguna disfunción, ya sea parcial o total, en los órganos que participan en la comunicación), ideológicos (vinculados con el contexto sociocultural y político de quienes establecen la comunicación) y psicológicos (parten de la manera particular del ser humano de percibir y concebir el mundo).

B. Habilidades Sociales

La conducta de una persona está formada principalmente por creencias, valores, y experiencias, que ha adquirido durante la vida; y las habilidades sociales están relacionadas con la conducta social de una persona. Según [2], la conducta socialmente habilidosa es el conjunto de conductas emitidas por un individuo en un contexto interpersonal, que expresa los sentimientos, actitudes, deseos u opiniones de ese individuo.

Existen varias clasificaciones de las habilidades sociales. Por ejemplo, según [24], las habilidades sociales se dividen en dos grupos: habilidades racionales (las relacionadas con el desempeño en determinadas tareas y con la capacidad de pensar) y habilidades emocionales (habilidades de cada individuo a nivel intrapersonal, y de interrelación con otros). Las habilidades sociales se utilizan dependiendo del contexto y los objetivos. Según [2], hay habilidades sociales generales: hacer y aceptar cumplidos, hacer peticiones, expresar amor y afecto, defender los derechos propios, expresar opiniones personales, expresar molestia o enfado, afrontar las críticas, solicitar un trabajo, hablar en público, entre otras.

Los elementos que constituyen cada habilidad social pueden agruparse, según [5], en tres tipos: conductuales (aquellos que pueden ser directamente observados por cualquier persona), cognitivos (incluye las competencias, constructos personales, expectativas, referencias, valores subjetivos, planes de autorregulación, etc.) y fisiológicos (presión cardíaca, presión sanguínea, flujo sanguíneo, respuestas electrodermales, frecuencia respiratoria y respuestas electromiográficas).

Los elementos conductuales se dividen en: verbal (transmisión de mensajes a través de la palabra), no verbal (mensajes que se transmiten al mismo tiempo, pero de manera independiente de las palabras, como expresión facial, postura, contacto físico, apariencia personal, gestos, automanipulaciones, entre otros) y paraverbal (aspectos de la palabra hablada capaces de variar su sentido, pero no su contenido, como volumen de la voz, tono, timbre, fluidez verbal, velocidad, tiempo de habla, pausas y silencios).

La utilización de los elementos que constituyen las habilidades sociales se relacionan con los estilos de comunicación. Según [5], existen tres estilos de comunicación: inhibido, donde la persona se preocupa por satisfacer a los demás; agresivo, donde la persona defiende sus derechos de una manera que irrespeta los derechos de los demás; y asertivo, donde la persona defiende sus derechos, y se expresa respetando los derechos de los demás. Las personas utilizan los tres estilos de comunicación dependiendo de cada situación concreta. Sin embargo, cada persona tiene un estilo predominante. Según [25], los estilos de comunicación se pueden identificar con señales que son habituales para cada uno de ellos. Para el estilo inhibido: cabeza baja, gestos contraídos, mirada tímida, sonrisa nerviosa, volumen de voz bajo, etc. Para el estilo agresivo: mentón levantado, gestos tensos, mirada hostil, sonrisa burlona, volumen de voz alto y tono arrogante. Finalmente, para el estilo asertivo: cabeza erguida, gestos desinhibidos, mirada frontal, sonrisa franca, volumen de voz moderado y tono tranquilo. Adicionalmente, según [20], los estilos de comunicación son influenciados por los estados afectivos: el estilo inhibido se relaciona con los sentimientos de vergüenza, temor, ansiedad, etc.; el estilo agresivo está asociado con sentimientos de ira, rabia, frustración, etc.; y el estilo asertivo está relacionado con la capacidad de regular los sentimientos.

C. Estados Afectivos

Los estados afectivos presentes en el ser humano están asociados a las emociones y los sentimientos. Según [20], las emociones son impulsos o reacciones afectivas más o menos espontáneas, que surgen ante una situación que aparece de repente; por otro lado, los sentimientos son el resultado de las relaciones, vivencias y experiencias de la forma de actuar. Las emociones son adquiridas por complejos procesos de aprendizaje de una cultura, y por incorporación de vivencias personales (no son instintivas y tampoco innatas), y tienen una duración comprendida entre algunos segundos y varias horas. Por otro lado, los sentimientos son estados afectivos más complejos, estables, duraderos y menos intensos que las emociones, producto de una situación progresiva que ha dejado su huella. Las emociones se representan en el cuerpo y generan reacciones que son públicas y notorias. A diferencia, los sentimientos se representan en la mente y son privados. Según [24], la parte emocional del cerebro actúa con más fuerza y velocidad que la parte lógica, sin embargo, esta última puede actuar como freno de la parte emocional.

Existen numerosas emociones, y muchas mezclas o variaciones entre ellas. Los investigadores no terminan de ponerse de acuerdo con respecto a las emociones que pueden considerarse primarias, de las que se derivan todas las demás. Sin embargo, según [26], existen seis emociones básicas (alegría, ira, miedo, sorpresa, asco y tristeza), también denominadas como emociones universales. Por otro lado, en [27] se presenta la siguiente clasificación de las emociones: positivas (felicidad, paz, admiración, empatía, bondad, amor, placer, fe, entre otras) y negativas (miedo, ansiedad, angustia, desesperación, estrés, odio, ira, rencor, rabia, culpa, vergüenza, resentimiento, tristeza, asco, celos, soledad, decepción, egoísmo, entre otras). En [28] se presenta una clasificación de los sentimientos: personales (orgullo, vanidad, ambición, superación y dominio), sociales (estima, empatía, gratitud, benevolencia, caridad, compasión y solidaridad), antisociales (envidia, desdén, antipatía e indiferencia) y superiores (responsabilidad, contemplación, excelencia, y piedad). Las emociones y los sentimientos son confundidos frecuentemente.

Los pensamientos y las ideas son un factor clave para las emociones, tal como lo explica [27], porque las emociones además de generar acciones, pueden también crear sentimientos, cuando éstas se hacen conscientes. Adicionalmente, hace énfasis en que muchas de las respuestas se generan de manera automática, por haberse dejado llevar por

las emociones. Según [24], los sentimientos son conscientes y las emociones son habitualmente inconscientes.

D. La Mente

Los procesos de la mente no son controlados completamente por las personas, ya que intervienen elementos de los cuales no son conscientes, pero que influyen en las decisiones. Según [29], para Freud la estructuración de la mente está segmentada en tres estratos que desarrollan entre sí una compleja sinergia: el Ello (sede de los impulsos más primitivos), el Yo (correspondiente a la mente reflexiva que ofrece la función de adaptación a la realidad circundante, e intenta frenar las pulsiones potentes provenientes del Ello) y el Superyó (residencia de las pautas que inculca la cultura, opuestas a los impulsos emanados del Ello y guardián del Yo).

Por otro lado, según [30], Freud postuló tres niveles de la conciencia: consciente (referida a las experiencias de las cuales la persona se da cuenta, incluyendo los recuerdos y las acciones intencionales), preconsciente (material del cual la persona no se percata en un momento, pero que puede ser traído con rapidez a su atención) e inconsciente (referido a los procesos mentales de los cuales la persona no se da cuenta. Se dice que este material se encuentra reprimido).

La distinción entre consciente e inconsciente, se presenta en [31], como dos modos de pensamiento denominados: sistema 1 y sistema 2. El sistema 1 es consciente, racional, tiene creencias, hace elecciones, decide que pensar, y centra la atención en las actividades mentales que demandan esfuerzo. Por otra parte, el sistema 2 opera de manera rápida y automática, con poco o ningún esfuerzo, y sin sensación de control voluntario, incluyendo destrezas innatas y actividades mentales que se vuelven rápidas y automáticas con la práctica prolongada.

En la psicología cognitiva se presenta otra distinción similar [32], entre el pensamiento racional y el pensamiento intuitivo. El pensamiento racional es consciente de sí mismo, controlado, e incluye al pensar lógico. Por otro lado, el pensamiento intuitivo es automático, y lleva los procesos de percepción hasta los niveles inconscientes del pensar. En general, las actividades ocurren en el pensamiento racional, y se desplazan hacia el nivel intuitivo con el paso del tiempo; por ejemplo, cuando una persona aprende a usar el teclado o tocar un instrumento musical. El comportamiento de una persona está determinado por la combinación de las fuerzas conscientes e inconscientes.

IV. Modelo de Interacción Humano-Humano (MIHH)

La Interacción Humano-Humano involucra elementos del lugar donde se desenvuelve la interacción, y elementos internos de cada persona. En ese sentido, para construir el MIHH (modelo propuesto en este trabajo) se han extraído de la literatura consultada 14 premisas, que están relacionadas con los componentes que deberían formar parte del modelo. En la Tabla I se presentan las premisas, junto con los componentes del modelo vinculados con dichas premisa.

Tabla I: Premisas del Modelo de Interacción Humano-Humano

N	Premisa	Referencias	Componentes involucrados
1	El canal de comunicación puede afectar el mensaje original.	Barreras físicas [1].	Canal y ruidos del canal.
2	Las condiciones ambientales pueden ser distintas para las personas que interactúan.	Condiciones del entorno [16].	Condiciones ambientales.
3	La percepción está influenciada por las condiciones fisiológicas de las personas.	Barreras fisiológicas [1].	Percepción y condiciones fisiológicas.
4	Las respuestas están influenciadas por las condiciones fisiológicas de la personas.	Barreras fisiológicas [1].	Actuación y condiciones fisiológicas.
5	La comprensión está influenciada por los conocimientos de la personas.	Barreras semánticas [1].	Filtros cognitivos.
6	Las respuestas automáticas son influenciadas por el inconsciente.	Inconsciente [30].	Inconsciente.
7	Las respuestas racionales son influenciadas por el consciente.	Consciente [30].	Consciente.
8	El estilo inhibido está influenciado por el temor y la ansiedad.	Inhibido [20].	Emociones y sentimientos.
9	El estilo agresivo está influenciado por la ira, la rabia y el rencor.	Agresivo [20].	Emociones y sentimientos.
10	El estilo asertivo está asociado con la capacidad de regular las emociones.	Asertivo [20].	Consciente.
11	Las personas responden con palabras.	Verbales [2][5].	Verbal.
12	Las personas responden con cambios en su lenguaje corporal.	No verbales [2][5].	No verbal.
13	Las personas responden variando la voz.	Paraverbales [5].	Paraverbal.
14	Las personas varían sus condiciones fisiológicas durante la interacción.	Fisiológicos [5].	Fisiológico.

La agrupación de los componentes conforman los módulos del modelo propuesto, y luego, la agrupación de los módulos establecen los niveles. En ese orden de ideas, se crean 6 módulos que se distribuyen en 2 niveles. En el nivel externo están: módulo individual (condiciones ambientales) y módulo compartido (canal y ruidos del canal). En el nivel interno, se tienen los siguientes módulos: físico (percepción, actuación y condiciones fisiológicas), afectivo (emociones y sentimientos), cognitivo (filtros cognitivos, consciente e inconsciente) y conductual (verbal, no verbal, paraverbal y fisiológico). Las relaciones de los módulos se realizan tomando en cuenta 4 consideraciones, que también son extraídas de la literatura consultada. En la Tabla II se presentan las consideraciones, con sus respectivas referencias y relaciones.

Tabla II: Consideraciones del Modelo de Interacción Humano-Humano

N	Consideración	Referencias	Relaciones
1	Los estados afectivos influyen en la percepción antes de ser procesada cognitivamente.	La parte lógica del cerebro puede actuar como freno de la parte emocional [24].	R1 y R2.
2	Los pensamientos pueden influir en los estados afectivos.	Cuando las emociones se hacen conscientes pueden crear sentimientos [27].	R3.
3	Los pensamientos controlan la conducta.	El comportamiento está determinado por la combinación del consciente y el inconsciente [32].	R4 y R5.
4	La información que viaja de una persona a otra es influenciada por el ambiente y el canal.	Condiciones del entorno [16] y barreras físicas [1].	R6, R7, R8 y R9.

A partir de las 14 premisas y las 4 consideraciones presentadas anteriormente, se construye el MIHH (ver Figura 1), que en términos generales está constituido por 2 niveles: el nivel externo asociado al medio por donde viaja la información de una persona a otra y el nivel interno relacionado con la particularidad propia de cada persona para percibir, procesar y enviar la información. A su vez, el nivel externo está constituido por dos módulos: individual, que influye en la información que viaja entre la persona y el canal de comunicación; y compartido, que influye en la información según los ruidos del canal. Por otro lado, el nivel interno está constituido por cuatro módulos: físico, que influye en la información según las condiciones fisiológicas de la persona; afectivo, que activa emociones y sentimientos; cognitivo, que toma las decisiones; y conductual, que incorpora los componentes observables a las respuestas. Los módulos del modelo participan en todo el proceso de interacción, interviniendo cada uno en mayor o menor medida, según el contexto y las personas involucradas.

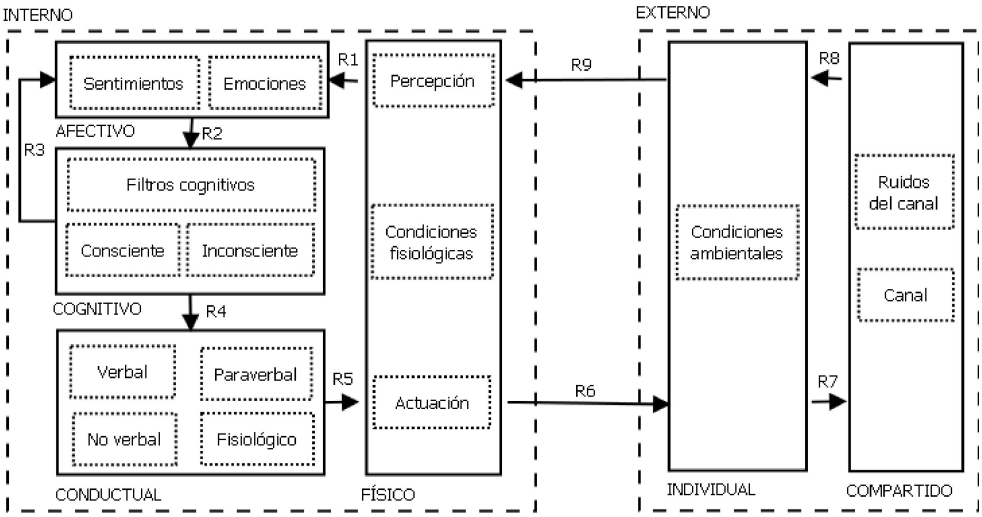

Figura 1: Modelo de Interacción Humano-Humano (MIHH)

A. Nivel Externo

El proceso de interacción consiste en el envío de información de una persona a otra y viceversa. Esa información, es enviada a través de un canal de comunicación que puede alterar la información original. Adicionalmente, la información también puede ser alterada durante el camino recorrido desde que es generada por la persona hasta que es incorporada al canal de comunicación, o viceversa. En ese sentido, el nivel externo se divide en dos módulos: individual y compartido. El nivel externo se alimenta de las respuestas generadas por las personas. Lo primero que hace es alterar la información de entrada según las condiciones ambientales presentes entre la persona y el canal. Luego, incorpora la información al canal de comunicación, y la modifica según los ruidos del canal. Finalmente, desincorpora la información del canal, y la modifica según las condiciones ambientales presentes entre el canal y la otra persona, lo cual representa la salida de este nivel. La descripción del proceso de este nivel se presenta en la Tabla III.

Tabla III: Descripción del Proceso del Nivel Externo

Entrada:	1. Respuesta generada en el nivel interno
Proceso:	1. Modifica la entrada según las condiciones ambientales (módulo individual de quien envía) 2. Incorpora la información al canal (módulo compartido) 3. Modifica la información con los ruidos del canal (módulo compartido) 4. Desincorpora la información del canal (módulo compartido) 5. Modifica la información según las condiciones ambientales presentes entre el canal y la otra persona (módulo individual de la otra persona)
Salida:	1. Información modificada

1) Módulo Individual: la respuesta que genera una persona es modificada por elementos del ambiente, que se encuentran entre la persona y el canal de comunicación, y que pueden ser diferentes para las personas involucradas en la interacción. Este módulo se encuentra ubicado entre el nivel interno y el módulo compartido, y está constituido por el componente de condiciones ambientales, para eliminar, modificar y agregar elementos a la información que procesa. La entrada de este módulo depende del sentido de la información, sin embargo, el proceso que realiza siempre consiste en modificar la entrada según las condiciones ambientales. La descripción del proceso de este módulo cuando la entrada es la respuesta generada en el nivel interno, se presenta en la Tabla IV.

Tabla IV: Descripción del Proceso del Módulo Individual Cuando se Alimenta del Nivel Interno

Entrada:	1. Respuesta generada en el nivel interno
Proceso:	1. Modifica la entrada según las condiciones ambientales presentes entre la persona y el canal. (componente condiciones ambientales)
Salida:	1. Información modificada

2) Módulo Compartido: la información viaja de una persona a otra mediante el canal de comunicación, donde pueden aparecer ruidos que modifiquen la información original. Así, este módulo está constituido por dos componentes: canal y ruidos del canal. La información que recibe proviene del módulo individual, y es modificada según

los ruidos presentes en el canal (ver la descripción del proceso en la Tabla V).

Tabla V: Descripción del Proceso del Módulo Compartido

Entrada:	1. Información proveniente del módulo individual
Proceso:	1. Incorpora la información al canal (componente canal) 2. Modifica la información según los ruidos del canal (componente ruidos del canal) 3. Desincorpora la información del canal (componente canal)
Salida:	1. Información modificada

B. Nivel Interno

Las personas tienen su manera particular de percibir, procesar y generar respuestas. En ese sentido, el nivel interno incluye los elementos que hacen que cada persona sea particular durante las interacciones. Este nivel está constituido por cuatro módulos: físico, afectivo, cognitivo, y conductual. El nivel interno se alimenta de la información que proviene del nivel externo, modificándola según la calidad de los sentidos y activando estados afectivos según la interpretación dada. Luego, se hace una nueva interpretación según los filtros cognitivos de la persona, para determinar la intención de comunicación de la otra persona, activando estados afectivos nuevamente. Después, se genera el objetivo y el estilo de comunicación, a partir de los aportes realizados inconsciente y conscientemente, y de los estados afectivos. Finalmente, a la respuesta se le asignan los componentes conductuales según el objetivo y el estilo de comunicación, restringidos por las condiciones fisiológicas de la persona (ver en la Tabla VI la descripción del proceso).

Tabla VI: Descripción del Proceso del Nivel Interno

Entrada:	1. Información proveniente del nivel externo
Proceso:	1. Interpreta la información según condiciones fisiológicas presentes en los sentidos (módulo físico) 2. Activa emociones y sentimientos según la interpretación realizada (módulo afectivo) 3. Interpreta la información según los filtros cognitivos (módulo cognitivo) 4. Identifica inconscientemente una intención en la comunicación (módulo cognitivo) 5. Identifica conscientemente una intención en la comunicación (módulo cognitivo) 6. Determina la intención general (módulo cognitivo) 7. Genera inconscientemente un objetivo y un estilo de comunicación (módulo cognitivo) 8. Genera conscientemente un objetivo y un estilo de comunicación (módulo cognitivo) 9. Activa emociones y sentimientos según objetivos y estilos de comunicación generados (módulo afectivo) 10. Genera el objetivo y el estilo de comunicación (módulo cognitivo) 11. Asigna componentes (verbal, no verbal, entre otros) a la respuesta (módulo conductual) 12. Modifica la respuesta según las condiciones fisiológicas presentes en la persona (módulo físico)
Salida:	1. Respuesta generada

1) Módulo Físico: las personas están limitadas biológicamente para percibir y actuar, por lo tanto, dependiendo de la calidad de los órganos y partes del cuerpo (ojo, oído, lengua, piel, nariz, músculos, etc.), la información percibida del módulo individual o la información proporcionada por el módulo conductual es interpretada o ajustada, respectivamente. Este módulo está formado por tres componentes: percepción, condiciones fisiológicas y actuación. Si la información proviene del módulo individual, es percibida a través de los cinco sentidos, generando como salida la información captada por los órganos biológicos, interviniendo los componentes: percepción y condiciones fisiológicas. Por otro lado, si la información proviene del módulo conductual, se ajusta dependiendo de las condiciones fisiológicas de la persona, interviniendo los componentes: actuación y condiciones fisiológicas. Uno de los procesos de este módulo es mostrado en la Tabla VII, cuando la entrada viene del módulo individual.

Tabla VII: Descripción del Proceso del Módulo Físico Cuando se Alimenta del Módulo Individual

Entrada:	1. Información proveniente del módulo individual
Proceso:	1. Interpreta la información según las condiciones fisiológicas presentes en los sentidos (componentes: percepción y condiciones fisiológicas)
Salida:	1. Información interpretada

2) Módulo Afectivo: el factor afectivo influye significativamente en los seres humanos, tanto en la interpretación de la información percibida como en la generación de respuestas. En general, las personas evocan estados afectivos según la información que procesan. En ese sentido, el módulo afectivo está formado por dos componentes: emociones y sentimientos. Ambos componentes reciben la información percibida del módulo físico, y los objetivos y estilos de comunicación generados en el módulo cognitivo, con el propósito de activar, desactivar o cambiar emociones y sentimientos. Las salidas del módulo afectivo son enviadas al módulo cognitivo, con la finalidad de comunicar el estado de los dos componentes. Adicionalmente, la información recibida del módulo físico es enviada al módulo cognitivo sin modificaciones (ver la descripción del proceso en la Tabla VIII).

Tabla VIII: Descripción del Proceso del Módulo Afectivo

Entrada:	1. Información proveniente del módulo físico 2. Información proveniente del módulo cognitivo
Proceso:	1. Activa emociones y sentimientos según la información recibida del módulo físico (componentes: emociones y sentimientos) 2. Activa emociones y sentimientos según la información recibida del módulo cognitivo (componentes: emociones y sentimientos)
Salida:	1. Información recibida del módulo físico 2. Emoción activada 3. Sentimiento activado

3) Módulo Cognitivo: en este módulo se identifica la intención de comunicación de la otra persona, y se generan tanto el objetivo como el estilo de comunicación de la respuesta. El módulo está compuesto por tres componentes: filtros cognitivos, inconsciente y consciente. Se alimenta directamente del módulo afectivo, con la información percibida y los estados afectivos actuales: emoción y sentimiento. El componente de los filtros cognitivos interpreta la información percibida según características propias de la persona, tales como: contexto sociocultural en el que se desenvuelve, personalidad, y el significado que le da a

las palabras. Los otros dos componentes se encargan de identificar la intención de comunicación de la otra persona, para generar el objetivo y el estilo de comunicación de la respuesta. Para identificar la intención y generar tanto el objetivo como el estilo de comunicación, los componentes consciente e inconsciente, primero, realizan el proceso por separado, después, envían los resultados parciales al módulo afectivo, y luego, establecen los valores a considerar conjuntamente. Finalmente, el objetivo y el estilo de comunicación son enviados al módulo conductual. Dependiendo de la intervención de los componentes de este módulo, se pueden generar dos tipos de respuestas: automáticas y racionales. Las respuestas automáticas son rápidas e instintivas, y se producen inconscientemente, por lo tanto, los componentes que participan son: filtros cognitivos e inconsciente. Las respuestas racionales son lentas, y se producen cuando predomina el consciente, por lo tanto, en este caso participan todos los componentes (ver Tabla IX).

Tabla IX: Descripción del Proceso del Módulo Cognitivo

Entrada:	1. Información proveniente del módulo físico 2. Emoción activada 3. Sentimiento activado
Proceso:	1. Interpreta la información según los filtros cognitivos (componente filtros cognitivos) 2. Identifica inconscientemente una intención en la comunicación (componente inconsciente) 3. Identifica conscientemente una intención en la comunicación (componente consciente) 4. Determina la intención general (componente consciente) 5. Genera inconscientemente un objetivo y un estilo de comunicación (componente inconsciente) 6. Genera conscientemente un objetivo y un estilo de comunicación (componente consciente) 7. Envía los objetivos y los estilos de comunicación generados al módulo afectivo (componentes: consciente e inconsciente) 8. Genera el objetivo y el estilo de comunicación (componente consciente)
Salida:	1. Objetivos de comunicación 2. Estilos de comunicación

Tabla X: Descripción del Proceso del Módulo Conductual

Entrada:	1. Objetivo de comunicación 2. Estilo de comunicación
Proceso:	1. Asigna el componente verbal a la respuesta según las entradas (componente verbal) 2. Asigna el componente paraverbal a la respuesta según las entradas (componente paraverbal) 3. Asigna el componente no verbal a la respuesta según las entradas (componente no verbal) 4. Asigna el componente fisiológico a la respuesta según las entradas (componente fisiológico)
Salida:	1. Respuesta

1) Módulo Conductual: las respuestas que generan las personas tienen un componente conductual que se manifiesta en el cuerpo, relacionado con lo que otras personas perciben. El módulo conductual está formado por cuatro componentes: verbal, paraverbal, no verbal y fisiológico. La participación de cada componente depende del objetivo y el estilo de comunicación, con el propósito de construir la respuesta. El componente verbal está compuesto por palabras; el componente paraverbal incluye: volumen de la voz, tono, timbre, entre otros; el componente no verbal incluye: expresión facial, entre otros; y el componente fisiológico incluye: la presión cardíaca, la presión sanguínea, el flujo sanguíneo, entre otros. La descripción del proceso de este módulo se presenta en la Tabla X.

V. Experimento

El objetivo del experimento es validar el MIHH directamente con personas. La validación es exitosa si se cumplen las premisas que fundamentan el modelo (ver sección 4), por lo tanto, el experimento consiste en proporcionar estímulos a las personas participantes (grupo experimental) que permiten evaluar cada premisa. El grupo experimental está formado por 30 estudiantes (23 hombres y 7 mujeres) de la carrera de Ingeniería de Sistemas de la Universidad de Los Andes, con edades comprendidas entre 17 y 26 años.

Tabla XI: Verificación de las Primeras 7 Premisas

Premisa	Estímulo	Pregunta	Verificación
1	Se coloca música en el ambiente	¿Qué canción está escuchando?	Si todos escuchan la canción del ambiente
2	Se pide al participante que se coloque los audífonos	¿Qué canción está escuchando?	Si todos escuchan la canción de los audífonos
3	Se pide al participante que lea la frase escrita en la hoja	¿Puede leer las letras sin moverse?	Si algunos pueden leer las letras sin moverse
4	Se pide al participante que se toque la punta del pie sin doblar las rodillas	¿Puede tocarse la punta del pie sin flexionar las rodillas?	Si algunos pueden tocarse la punta del pie
5	Se pide al participante que señale el hueso húmero	¿Sabe dónde está el hueso húmero?	Si algunos saben dónde está el hueso húmero
6	Se pide al participante que diga su nombre	¿Tuvo que pensar para responder la pregunta? **Observador:** ¿Respondió rápido?	Si los que responden rápido no piensan
7	Se pide al participante que diga cuántas consonantes tiene su segundo apellido	¿Tuvo que pensar para responder la pregunta? **Observador:** ¿Respondió rápido?	Si los que responden lento piensan

En cada experimento participan: el observador (persona que observa el experimento y valida las respuestas del estudiante), el entrevistador (persona que proporciona los estímulos y hace las preguntas al estudiante) y un estudiante. El experimento se realiza en un espacio acondicionado adecuadamente con las mismas condiciones para cada estudiante, las cuales son: el entrevistador y el estudiante están sentados en sillas ubicadas frente a frente a una distancia aproximada de 1.5 metros, y el observador sentado al lado derecho del entrevistador. La evaluación de las primeras 7 premisas se realiza aplicando una entrevista rápida de 7 preguntas que ameritan respuestas cerradas. Para cada premisa, el entrevistador proporciona un estímulo y hace una pregunta, y el observador anota las respuestas del estudiante. De manera particular, para las premisas 6 y 7, el observador anota si el estudiante responde rápido o no (ver Tabla XI). Con respecto a la verificación, las

premisas 1 y 2 se validan si todos los estudiantes escuchan la canción correspondiente, las premisas 3, 4 y 5 si los estudiantes responden de manera afirmativa, y las premisas 6 y 7 si las respuestas de los estudiantes coinciden con lo anotado por el observador.

Las características de las últimas 7 premisas permiten hacer la evaluación proporcionando sólo un estímulo (se pide al participante que mencione su opinión sobre la situación del país) que requiere una respuesta de desarrollo, haciendo una pregunta cerrada (En su opinión ¿predominó la vergüenza, el temor, la ansiedad, la ira, la rabia o el rencor?) y anotando las percepciones del observador (ver Tabla XII). Las premisas 8 y 9 se verifican si hay coincidencia entre la anotación del observador y la sensación del participante; las premisas 10, 11, 12 y 13 se verifican si las anotaciones del observador son afirmativas; la premisa 14 se verifica si la medición de la frecuencia cardíaca cambia (se mide con una aplicación de Android denominada "Instant Heart Rate").

Tabla XII: Verificación de las Últimas 7 Premisas

Premisa	Observación	Verificación
8	¿Utiliza estilo inhibido?	Si el observador percibe inhibido al estudiante y el estudiante responde vergüenza, temor o ansiedad.
9	¿Utiliza estilo agresivo?	Si el observador percibe agresivo al estudiante y el estudiante responde ira, rabia o rencor.
10	¿Utiliza estilo asertivo?	Si el observador percibe asertivo al estudiante.
11	¿Utiliza palabras para responder?	Si usa palabras en la respuesta.
12	¿Hace gestos o cambios de postura?	Si hace gestos o cambia la postura.
13	¿Hace variaciones en la voz?	Si hace variaciones en la voz.
14	¿Hay variaciones en su frecuencia cardíaca?	Si su frecuencia cardíaca varía.

VI. Resultados

Los resultados obtenidos permiten comprobar las 14 premisas satisfactoriamente (ver Tabla XIII). Las premisas 1, 2, 6, 11, 12 y 14 se comprueban en el 100% de los casos, es decir, los 30 participantes respondieron de manera favorable a estas premisas. En ese sentido, se puede decir que todos los participantes escucharon las canciones del ambiente y audífonos mientras respondían las preguntas, que decir el nombre es una respuesta automática, y que durante la interacción todos variaron sus palabras, lenguaje corporal y frecuencia cardíaca. Las premisas 3, 4 y 5 se comprueban porque sólo algunos participantes respondieron afirmativamente, específicamente 53.3%, 90% y 6.7% respectivamente. Al respecto, el 53,3% puede leer las letras de tamaño 12 a una distancia de aproximadamente un metro y medio, el 90% puede tocarse la punta del pie sin flexionar las rodillas y el 6.7% conoce la ubicación del hueso húmero.

En la premisa 7, aunque no se comprueba en el 100% de los casos que indicar la cantidad de consonantes que tiene el segundo apellido es una respuesta racional, se comprueba en el 96.7% de los casos; sin embargo, el 3.3% que indicó que había sido una respuesta sin pensar, coincide con que la respuesta fue rápida, por lo tanto, este 3.3% se puede catalogar como respuesta automática. Por otra parte, las premisas 8 y 9 se comprueban en todos los casos donde fue detectado inhibido y agresivo el estudiante por parte del observador, los cuales representan el 16.7% y 23.3% del total, respectivamente. En el resto de los casos donde el observador detectó asertivo, que representa el 60% del total, se obtuvieron como respuestas sensaciones de ansiedad y rabia, lo cual muestra la capacidad de regular esas sensaciones para lograr expresarse con un estilo asertivo de comunicación. Finalmente, en la premisa 13, el 83.3% de los estudiantes hace variaciones en la voz durante la interacción, lo cual verifica la premisa de que las respuestas de las personas involucran variaciones en el tono y ritmo de la voz. En el 16.7% restante, donde no se detectaron cambios en la voz, no necesariamente significa que los participantes no hayan realizado cambios en la voz, porque las variaciones se midieron con la percepción del observador, por lo tanto, no se descarta que se hayan realizado cambios que pueden ser detectados y medidos por algún instrumento especializado.

Tabla XIII: Resultados del Experimento

Premisa	Resultados
1	El 100% escucha la canción del ambiente.
2	El 100% escucha la canción de los audífonos.
3	El 53,3 % responden que si pueden leer las letras sin moverse y los demás responden que no.
4	El 90% responde que si puede tocarse la punta del pie y los demás responden que no.
5	El 6,7 % responde que si saben dónde está el hueso húmero y los demás responden que no.
6	El 100% respondió rápido y dijeron que no habían pensado.
7	El 96,7 % no respondió rápido y dijeron que si habían pensado. El 3,3 % que respondió rápido, coincidió con que no habían pensado.
8	El 100% de los inhibidos detectados (16,7% del total) coincidió con sensaciones de ansiedad y temor.
9	El 100% de los agresivos detectados (23,3% del total) coincidió con sensaciones de rabia e ira.
10	El 100% de los asertivos detectados (60% del total) coincidió ansiedad y rabia.
11	El 100% utiliza palabras.
12	El 100% cambia el lenguaje corporal.
13	El 83,3 % hace variaciones de la voz.
14	El 100% tiene variaciones en la frecuencia cardiaca.

En general, se puede decir que las premisas que se cumplieron en el 100% de los casos representan aspectos robustos del modelo. Por otra parte, las premisas que se cumplieron parcialmente, son aspectos del modelo que se adaptan según las características de las personas cuando interactúan, tal que esas premisas son válidas en cada estudiante según ciertas condiciones. Por ejemplo, para la premisa 5, que está relacionada con la influencia de los conocimientos en la comprensión de las personas, se cumple bajo la condición de que algunos estudiantes tienen ciertos conocimientos del cuerpo humano y otros no.

VII. Evaluación del MIHH

La evaluación del MIHH propuesto se hace de manera cualitativa, según los lineamientos de la metodología DESMET para el análisis de características. Este método de evaluación es denominado *Qualitative Screening* y se utiliza cuando se comparan varios modelos, cuya estrategia más simple consiste en marcar la existencia de cada característica en cada modelo [33]. Las características determinadas son seis, estando dos de ellas asociadas al nivel externo, y las demás al nivel interno. Las características asociadas al nivel externo son: el mensaje

que se transmite [13] y los ruidos del canal que perturban la comunicación y/o el mensaje [1]. Por otro lado, las características del nivel interno son: la cognición de las personas [32], las condiciones físicas de las personas [16], la influencia de los estados afectivos [20] y la influencia del inconsciente [30]. En la Tabla XIV se presentan las características existentes en cada modelo comparado.

Tabla XIV: Comparación de Modelos de Comunicación

Modelo	Mensaje	Ruidos en el canal	Cognición de la persona	Condiciones físicas de la persona	Influencia de los estados afectivos	Influencia del inconsciente
Aristotélico de la retorica	✓					
Comunicación de Shannon	✓	✓				
Comunicación de Casado	✓	✓	✓			
Comunicación verbal de León	✓	✓	✓			
Sinérgico de la comunicación	✓	✓	✓	✓		
Modelo propuesto (MIHH)	✓	✓	✓	✓	✓	✓

El modelo aristotélico de la retórica [13] es el más simple porque sólo considera la comunicación desde el orador hacia los oyentes y hace énfasis en el discurso, es decir, el mensaje que se intenta transmitir. Con respecto al MIHH, este último puede explicar con mayor detalle el proceso de construcción del discurso a través de los módulos que componen el nivel interno.

En cuanto al modelo de Shannon [18], en el nivel interno del modelo propuesto en este trabajo se incluyen: la fuente de información, el transmisor, el receptor y el destino. Por otra parte, en el nivel externo, la respuesta generada es la señal emitida, los ruidos del canal representan la fuente de ruido y la entrada del módulo físico representa la señal recibida. Adicionalmente, como aporte a modelos genéricos de comunicación, se puede apreciar que el MIHH, a diferencia del modelo de Shannon, considera tres tipos de ruidos: ruidos que aparecen antes de incorporar la información al canal de comunicación (condiciones ambientales del emisor), ruidos que están presentes en el canal (ruidos del canal), y ruidos que aparecen después de desincorporar la información del canal (condiciones ambientales del receptor).

El modelo de Casado [7] explica la comunicación interpersonal a través de fases, considerando incluso una fase anterior y otra fase posterior, e incluyendo diferentes objetivos en cada fase que están relacionados con las habilidades sociales (iniciar conversaciones, expresar opiniones, hacer preguntas, etc.), pero sin enfocarse en cómo se generan. Por una parte, esas fases pueden ser descritas en el nivel externo del MIHH, y en el caso de la entrevista psicológica, el nivel interno puede aportar la descripción de cómo se generan esas interacciones.

El modelo de comunicación verbal de León [1] describe el proceso de comunicación en un flujo de información oral y escrita, incluyendo dos módulos característicos que no se presentan en otros modelos: expresión y captación. El módulo de expresión se ocupa del proceso de codificación a través de la fonación o la escritura, y el módulo de captación describe el proceso de decodificación mediante la audición o la lectura. En el MIHH, el módulo de expresión corresponde con el módulo conductual, y el módulo de captación corresponde con el módulo físico. Adicionalmente, el MIHH considera aspectos de la comunicación oral y escrita que pueden enriquecer el modelo de León, tales como: verbales, paraverbales, no verbales y fisiológicos.

El modelo sinérgico [16] que concibe la comunicación como un proceso transaccional es el modelo que más se acerca al MIHH. En ese sentido, las características individuales de las personas, los aspectos sociales y los elementos culturales, están considerados en el nivel interno del MIHH. Los aspectos relacionados con el contexto como configuración y características del entorno se ven reflejados en el nivel externo del MIHH. Los elementos que no considera el modelo sinérgico son: los estados afectivos de las personas y la influencia del inconsciente en el proceso de interacción.

Para describir las interacciones entre personas, es importante considerar los aspectos propios y característicos de cada persona. Los modelos consultados en la literatura no presentan explícitamente esos aspectos, los cuales son importantes porque tienen influencia determinante en las interacciones. Los aspectos propios de cada persona que incorpora el MIHH son: estados afectivos e influencia del inconsciente. En ese sentido, el MIHH proporciona una descripción más completa del proceso de comunicación interpersonal.

VIII. Conclusiones

Los modelos de comunicación describen las interacciones entre personas de manera superficial, considerando principalmente el proceso externo de intercambio de información. En ese sentido, el objetivo del Modelo de Interacción Humano-Humano (MIHH) es describir de una manera más completa ese proceso de intercambio de información, incorporando elementos del proceso interno de cada persona. Los elementos que componen el modelo pueden aparecer en mayor o menor medida dependiendo del contexto de interacción.

En la descripción de las interacciones interpersonales, el MIHH permite explicar dos tipos de respuestas o comportamientos en las personas, que no pueden ser explicadas por otros modelos de comunicación: racionales y automáticas. Esas explicaciones son posibles por la aparición de los siguientes componentes: consciente e inconsciente. Adicionalmente, el MIHH también permite explicar el estilo de comunicación de cada persona, el cual puede variar entre

inhibido, asertivo y agresivo, y está asociado con los componentes: emociones y sentimientos. En general, se cumple el objetivo de proporcionar descripciones más completas del proceso de comunicación entre personas.

El interés de tener un modelo con estas características, está relacionado con trabajos futuros, que requieren inspiración del proceso de interacción entre personas. En particular, el MIHH es un insumo fundamental, ya que permite establecer un conjunto de elementos que deberán ser considerados en propuestas de modelos sobre la Interacción Humano-Robot. Los trabajos futuros están orientados hacia la definición de esquemas que permitan la interacción entre personas y máquinas, siguiendo los términos humanos de interacción. En ese sentido, por una parte, la representación en el MIHH del proceso interno de las personas, se convierte en la base para organizar el procesamiento de las máquinas, con el propósito de reproducir el comportamiento de las personas, y por otra parte, la representación del proceso externo de la comunicación, permite conocer los elementos que deben considerarse en el envío y la recepción de la información.

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Integrating a Unified Communications System with Social Networks

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Abstract: The increasing number of employees and clients, that are associated with each organization, has motivated them to extend their technological platform with the implementation of unified communications servers, with the goal of significantly improve their communication processes. On the one hand, people usually look for easy and fast methods for their communications. On the other hand, social networks have experienced an exponential boom in the last few years. Hence, in this research work, we propose a solution that allows the integration of a unified communications system with a social network. For the unified communications system, we choose Elastix, since it has become very popular and many companies worldwide have already based they communications system on it, whereas Twitter has been our selection for the social network, since it is commonly used for the exchange of short and accurate information among people. Our proposal is focused on the customer services offered by organizations to people, using Twitter.

Keywords: Customer Services; Unified Communications Systems; Elastix; Social Networks; Twitter; Integration.

I. Introduction

Nowadays, communication technologies are becoming so important that they form part of the strategic plan of organizations. In the actual globalized world, people take an important part of their workday to see emails, make calls, use instant messaging, and even participate in video-conferences to communicate with collaborators or customers. Therefore, communications systems have a great challenge ahead, which consists of offering the required tools to organizations with the aim of improving their way of doing business.

IP telephony is a technology that is implemented on top of the existing data networks. This technology has been in the market since the late nineties, but has not been widespread until recently, thanks to the improvement and standardization of the systems that provide voice quality control and the universalization of the Internet service. IP telephony usually brings an efficient and flexible environment in an organization for communications, and allows remote locations to be smoothly integrated into the headquarter.

On the other hand, social networks allow a fast, effective and simple interaction among a large number of people. The focus of the organizations in the usage of social networks cannot be limited to the advertisement of products and promotions, but must also point to the resolution of doubts and problems of customers, and to maintain this direct contact through the Internet.

In this work, we propose a solution to integrate or extend the functionalities of unified communications servers with social networks.

The rest of this document is organized as follows. In Section II, we present the problems faced by organizations with their communications platforms. In Section III, we introduce the different elements that were considered as possible part of a software solution. Related works are reviewed in Section IV. In Section V, we present our proposed software solution for the integration of unified communications systems with a social network. Section VI describes the scenarios used and the tests performed to validate our solution, while the results are discussed in Section VII. Finally, Section VIII concludes the paper and gives directions for future works.

II. Problems Faced by Organizations with their Communications Systems

As time goes by, the growing limitations of the old telephone system can be evidenced. For example, the conventional telephone system presents serious problems of scalability, especially when it comes to add new telephone lines. In addition, it also has low flexibility when the users want to develop and implement specific applications that meet the needs of a particular company. For these reasons, worldwide, we can observe that entities are migrating their telephone systems to VoIP.

In the last few years, usage of technology has increased significantly in all areas; in particular information technologies are now present in all processes carried out in our society. For example, social networks are now ubiquitous, leading most people to change both, their personal and professional behaviors.

However, even though social networks are becoming widespread, they are still rare in unified communications services, particularly in the following areas: process management, customer service, marketing, and advertising. These areas can be significantly supported and improved by integrating unified communications services with social networks. Currently, the integration between state-of-the-art telephone systems and social networks are practically non-existent; therefore, there is no work and substantial evidence of the benefits that social networks would offer to unified communications systems, by expanding the services currently available.

III. Study of the Possible Technologies

During the last decades, the experience offered to customers by call centers has evolved. This is due to the fact that the communication with the clients is not anymore only focused on incoming and outgoing voice calls, but now also integrates data applications like e-mail, web-based chat, instant messaging, and the capability to share pictures and web pages sent to and from the customers. Hence, the term "Call Center" is now becoming obsolete, and the one used nowadays is "Contact Center," with the encompassment of all communication channels with clients.

In our society, that has been flooded by social networks, it is logical to think that these channels of communications can be used not only for the interactions between individuals, but also to communicate customers with large companies and organizations. Through social networks, a user can request information about a product, generate a claim, express an opinion, or require services. In this research work, we propose the integration of two important technologies: (1) Elastix as the unified communications server and (2) Twitter for the social network.

A. Elastix

Elastix [1][2][3][4] is an open source software platform that aims to incorporate in a single solution all media and communication alternatives available in the business world [5]. Its functionality is based on the usage of four very important software programs: (1) Asterisk [6][7][8][9], (2) HylaFAX, (3) Openfire [10], and (4) Postfix [11][12][13]. These software provide functions of PBX (Private Branch Exchange), fax, instant messaging, and email, respectively.

1) Architecture: Elastix is not only in charge of providing telephony, but it also integrates other means of communications to make the work environment efficient and productive. By having an integration of different communication systems, an enhanced productivity is achieved in different aspects such as saving time and paper, facilitating the access to shared information, among others. Figure 1 shows the different layers of communications present in the general architecture of Elastix.

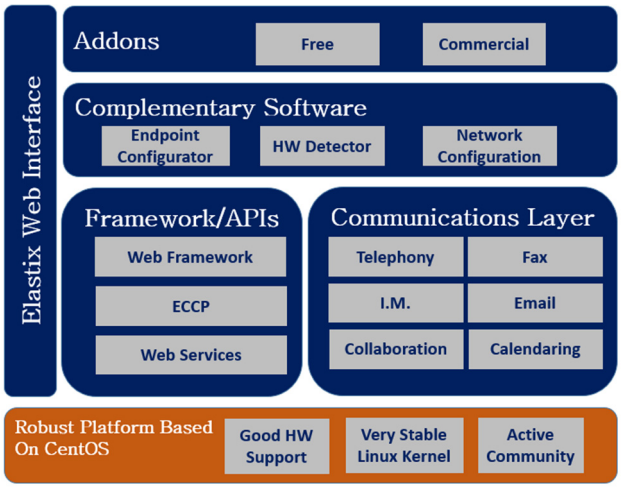

Figure 1: Architecture of Elastix

2) Characteristics: Elastix has multiple features and functionalities related to the services it provides: IP telephony, fax server, mail server, conferences, instant messaging, among others. These characteristics are provided by the software on which Elastix is based, mentioned above. The latest versions of Elastix allow third parties to develop software modules to improve the system, or to customize it for their own use. Below, we describe the technologies that help developing additional features to integrate them into Elastix.

Elastix Call Center Protocol (ECCP)

It is a text protocol based on XML and specialized for call centers. Its objective is to provide client applications with a single comprehensive protocol as an alternative to other existing protocols such as web services or AMI (Asterisk Manager Interface).

One of the disadvantages of this protocol was its performance, since initially, the only scheme available was based on the concept of "polling," which generated numerous queries to the server and an unnecessary waste of Elastix server resources. The new version of the protocol supports asynchronous events for communications, eliminating the need for "polling" and offering the possibility of a scalable solution.

This protocol provides a communications API (Application Programming Interface) available through a TCP port to which client applications can connect in order to communicate with the predictive dialer of Elastix, allowing third parties to develop their own agent consoles or other types of client applications.

Asterisk Gateway Interface (AGI)

This interface [14][15] is mainly used to add new features to Asterisk through the use of different programming languages, such as Perl, PHP, C, Pascal, among others. Its function is to connect the Asterisk dialplan with an external program that seeks to manipulate a channel in the dialplan. The interface is synchronous, i.e., the action taken on a channel by an AGI block does not return until the action is completed.

Asterisk Manager Interface (AMI)

AMI provides a mechanism to control where the channels are executed in the dialplan. Unlike AGI, AMI is an asynchronous interface, by events. For the most part, AMI does not offer mechanisms to control the channels' execution; rather it provides information about the state of the channels and where the channels are running.

Both interfaces (AGI and AMI) are powerful and open a wide range of integration possibilities. AGI enables the execution of the remote dialplan, which allows developers to control the channels in Asterisk using PHP, Python, Java, and other languages. With AMI, the Asterisk status can be displayed on the screen, calls can be initiated, and controlled channels can be located. By using both APIs together, it is possible to create complex applications using Asterisk as the engine for the development.

Asterisk RESTful Interface (ARI)

ARI allows developers to build custom communications applications. ARI exposes primitives of Asterisk that are normally reserved to C modules (channels, bridges, endpoints, communications media, etc.) through an intuitive REST interface. ARI transmits the state of the objects that are controlled by the users, through JSON [16][17] (JavaScript Object Notation) events over a WebSocket [18][19].

By giving control of the fundamental building blocks in Asterisk to all developers, regardless of the programming language, Asterisk is becoming a communications engine, with the business logic of how things should be communicated, delegated to the application using Asterisk.

ARI is not a substitute for AGI or AMI. Rather, it is a complementary API:

- AGI allows users to control the execution of dialplan applications on remote processes.
- AMI allows users to manage and control calls at a high level.
- ARI allows the replacement of dialplan applications with user-customized communications applications.

B. Social Networks

Social networks have revolutionized the concepts of personal relationships and entertainment. They are aimed to maintain contact with people, create new links, interchange information and opinions, and furthermore, they can be used in many other areas, such as finding job opportunities.

Every day, millions of people around the world use social networks such as Facebook and Twitter to express their opinions. This represents a valuable opportunity for organizations to know more about their actual or potential clients, in addition of reaching a greater number of people, that could not be done in a traditional way.

1) Principal Use of Social Networks: Initially, social networks were intended to connect people, with a focus on personal communications. However, over the years, they became a place where organizations can interact with customers and propose their products and services. According to the classification carried out by Del Moral [20], the four main usages of social networks are:

- Maintenance of friendships: keeping in touch with friends, colleagues or ex-partners of work, summer acquaintances, etc. In the past, before social networks, many of these relationships will not last in the long run, due to the difficulty and cost of communications.
- New friendships: while social networks facilitate the maintenance of contact between people who know each other, they also promote new contacts between people. For example, in most of these social networks, users can define friends. The list of friends is generally visible to other contacts and friends, who can in turn interact and meet each other. Thus, the friend of a friend can become a contact and later a friend of a third party. This converges on the "six degrees of separation" theory from Frigyes Karinthy, which suggested that we would not need to contact more than six people to find someone, following their networks of friends and acquaintances. In other words, any two people on the planet are linked, without knowing it, by a chain of friends or acquaintances, with a length of at most six people.
- Entertainment: although social networks serve to interact and increase relationships, there is also a profile of users who use them as an entertainment portal. These users explore the updates of the state of other users, that is, they inform themselves about other people's lives, they discover the new colleagues of former classmates, etc. It is a way of observing what is happening without being seen.
- Group of related people: it is one of the main usages of social networks. People that share the same interest or from the same professional sector can group themselves to discuss their common interest. Furthermore, some organizations create private social networks to streamline procedures, communications, conferences, or reports.

2) Usage Focused to Organizations: For organizations, it is important not to merely used social networks as an advertising platform. They must be integrated to promote socialization, the exchange of experiences, etc. In fact, using social networks mainly as a sales platform can generate a negative perception of the brand, given the social, rather than commercial, expectation that the term "social network" implies.

There are many benefits that a correct strategy for the usage of social networks can generate, and these will depend not only on the strategy as such, but also on other external factors such as the sector of the organization, the commercial activity, the size of the organization, the target community, and last but not least, the level of commitment of the organization with the implementation of a digital marketing plan.

3) APIs for Social Networks: An API (Application Programming Interface) is a set of functions/methods that provide the programmer with an interface of communications with a specific system, allowing him/her to develop new custom functionalities. In our days, social networks have information from users that is quite useful to promote products

and services. Currently, many applications are being designed in such a way that they have the ability to establish a connection with the API of these networks, and obtain relevant data from the users, in order to customize the information to be shown to them.

To establish such a connection, a process of authentication and permission authorization must be followed, through the usage of the "OAuth" protocol [21][22][23] (Open Authentication). This protocol allows a user to grant access to his/her data to a third party, without having to provide his/her username and password. In this process, when the user grants permission to the application, the social network provides a "token" that must be saved by the application in order to make requests on behalf of the user, such as reading personal information, interests, contacts, or publishing new information.

The interaction between social networks and the application is made through requests, sent with the HTTPS (Hypertext Transfer Protocol Secure) protocol [24]. According to the action to realize, requests of type GET, POST, PUT or DELETE can be used. These requests are analogous to the actions of reading, writing, editing or deleting, respectively. All requests must include the access "token" through which the request is validated, accepting or rejecting according to the permissions granted to the user. It is recommended to send the access token within the header of the requests, although it can also be sent as a parameter in the URL, since it is protected by the HTTPS protocol.

Even though all social networks have similar APIs, they have different restrictions for the management of data and a different usage in society.

Twitter

It is one of the social networks that has done a lot of efforts to promote its API. In fact, the statistics indicate that more than half of the accesses to their tweets are made from external applications, such as TweetDeck [25] or Seesmic. There are thousands of products developed from the API of Twitter. Some of them, that require a very high volume of information, pay for it, resulting in a new business model.

Twitter is one of the social networks that does not have many privacy restrictions, that is, the vast majority of users have a public profile, and therefore also are their "tweets." For this reason, Twitter allows access to all this information through its API.

One of the restrictions that developers face is the limit of requests that can be done in a period of time. That is, there are 15-minute intervals where a maximum number of requests can be made. It is worth mentioning that these limits are per user, not per application, allowing an independent control on each user. According to the type of resource that is requested, there are two main types of restrictions: (1) 15 requests every 15 minutes and (2) 180 requests every 15 minutes. Additionally, it is not allowed to retrieve historical information, that is, if a search is executed, it is only possible to obtain information generated in the previous seven days. In case of exceeding the maximum number of requests in a period of time, a response code is obtained which provides information about the temporarily restricted resource and the waiting time for the resource to be available again. However, Twitter also offers the usage of streaming, which allows the acquisition of information in real time, without restricting the number of requests for a period of time.

IV. Related Works

A few works have been done in relation to the integration of unified communications systems with social networks. In this section, we describe some of these works.

A. Integrating Elastix with Gtalk

The work carried out by Gaibor [26] consisted of the integration and configuration of the Gtalk instant messaging service in Elastix (see Figure 2). The author discovered that the Asterisk version which comes with Elastix 2.2 brings a compiled Gtalk support, allowing an easy communication with the service.

In the configuration process, the file of the XMPP protocol (formerly known as Jabber) had to be modified to create a user, by using a Gmail account. Then, a context for the user had to be made with a file of custom extensions, allowing the execution of a series of commands when calling the extensions. Finally, it was added to the dialplan and tests were done to verify the correct operation of the user.

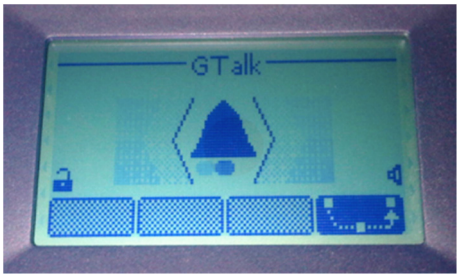

Figure 2: Call Received from a Google Account

B. Publication in Twitter through ASR

The work done by Smith [27] is about writing a tweet in a personal Twitter account, through a call to an extension and commenting the content of the tweet using an ASR (Automatic Speech Recognition), at no cost. Smith used PHP-AGI, a library to work with AGI from the PHP programming language, and wrote some scripts. The author also used a WAV (Waveform Audio Format) to FLAC [28] (Free Lossless Audio Codec) converter. WAV is a digital audio format that does not have data compression, while FLAC allows digital audio to be compressed without losing information. The conversion was required, since the solution uses the free ASR service [29] from Google that only receives FLAC formats. In order to convert from WAV to FLAC, Smith used the SoX [30] program, a famous tool to convert, add effects, and other advanced sound manipulation functions, on audio files, from a terminal.

Finally, Smith had to create and authorize an application in Twitter, so that the PHP script could work. The application required read, write, and access permissions to direct messages, in order to manipulate the account. The most important information that could be obtained from the application are: the consumer key, the consumer secret, the access token, and the access token secret.

V. Integrating Elastix with Twitter

Figure 3 depicts the conceptual design of the proposed solution, which is divided into two modules distributed in different physical servers. The elements involved in our solution are explained next.

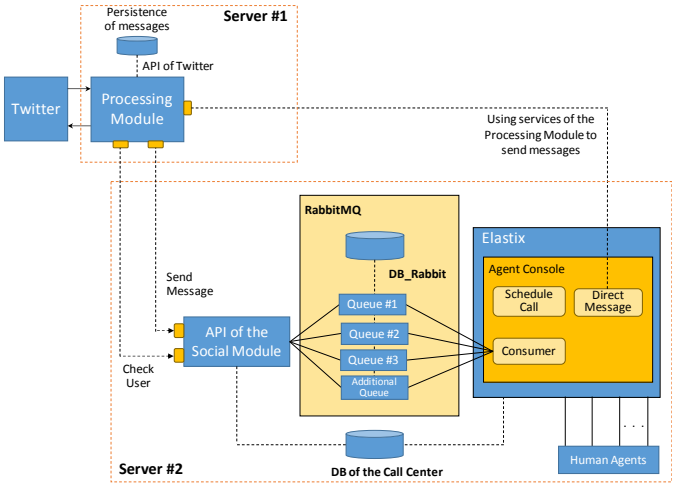

Figure 3: The Proposed Architecture to Integrate Social Media to Elastix

A. Twitter

It is a software component that acts as an intermediary between the organization and its clients. It receives the requests from the clients, sorts them, and publishes the associated responses. The interaction with the API of Twitter is based on having a Twitter account with permissions for third party apps, so the application can read and write direct messages. Direct messages is the tool that we selected to gather the important data used by the processing module (see Section V.B). Since the data exchanged can be sensible, we chose them since they offer an exclusive private bidirectional canal of communication with the owner of the account (client). In addition, unlike the tweets, direct messages do not have the limit of 140 characters in length, allowing the exchange of longer messages.

B. Processing Module

The processing module uses the services of the Twitter API to obtain and send direct messages to clients. Due to the asynchronous nature of the flows between Twitter and the social module (see Section V.C), it was necessary to label the direct messages with a tag since they can be in one of three possible states: (1) the direct message was satisfactory processed in the social module, (2) the direct message is been reviewed in the social module, and (3) the delivery of the direct message to the social module has failed.

This module was developed with the Rails framework [31] for the flexibilities and advantages it offers at the time of programming. We also used the REST architecture and the JSON [16][17] (JavaScript Object Notation) format for data transfer, due to their simplicity, their speed of processing, and since the Twitter API also manages these technologies. Figure 4 shows the different functionalities that reside in the processing module for the handling of messages from the social network.

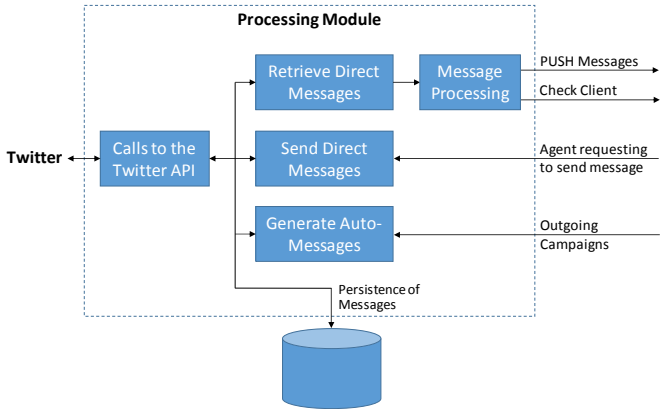

Figure 4: Processing Module - Elastix Social Media

1) Call to the Twitter API: This component is in charge of configuring the information of the account associated with Twitter, to make calls on behalf of the owner of the account. To do so, it uses a gem of Rails called "Twitter," and must obtain from the Twitter application some secret and unique values: consumer key, consumer secret, access token, and access token secret.

After the configuration and thanks to the used gem, it is possible to tweet, send and get direct messages through simple directives such as:

- create_direct_message(<ID_or_UserName>,<Message>): send a direct message without limit of characters to a user by specifying his/her ID (identification number) or username.
- direct_messages: retrieve all the direct messages of the configured account.
- update(<tweet>): update the timeline of the account by sending a new tweet (as previously specified, tweet are limited to 140 characters).

2) Retrieve Direct Messages and Message Processing: The function of these two components is to use the Twitter directives to obtain all direct messages and to perform the classification of the obtained messages. The classification is done as (1) complaint, (2) doubt, or (3) compliment, and messages have a specific structure depending on their classification.

The messages that are retrieved are stored in a database and the following labels are kept: waiting, delivered, and finished. These labels correspond to the receiving process of a message through the API, its submission to the social module for its attention, and the effective response of the agent to the user's request.

3) Send Direct Messages: It is a web service to be used by the agent for the submission of the answer to the request with a direct message to the user.

4) Generate Auto Messages: This component is used for automatic messages and outgoing campaigns. These messages

are classified as "Informative Tweets", "Outgoing Campaigns by Tweets," and "Outgoing Campaigns by Direct Messages".

C. *Social Module*

This component is in charge of the operations on the messages received by the processing module, in addition to providing support tools for the management of the contact centers in relation to their link with social networks. Its structure is part of the ecosystem of the unified communications server, where it maintains dependencies with the rest of its components. The "Social Module" in its operative scope maintains the management of the service queues and the distribution scheme of messages to the agents, allowing them to support their administration with the generation of calls, submission and reception of direct messages, management of outbound campaigns in social networks, among others. Figure 5 shows the components involved in the operation of the social module.

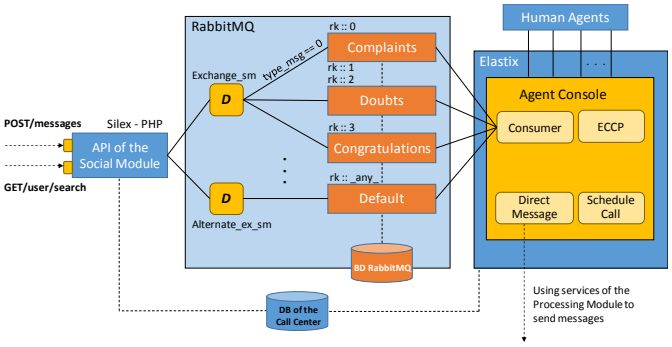

Figure 5: Social Module - Elastix Social Media

1) API of the Social Module: Given the approach proposed for the communication between modules, we implemented an API with Silex [32], a PHP micro-framework, to get an intermediary between the processing module and the service queues handled by the RabbitMQ message broker [33][34][35], which is responsible for providing the services required to complete the workflow of each message. In the following bullet list, two important REST web services are discussed:

- messages: service obtained through a POST request to enqueue in RabbitMQ a message previously processed and parsed in JSON format.
- /user/search: service obtained through a GET request, to verify the existence of a client within the module of the call center, by sending two of its identifiers (identification number and contract number).

2) Service Queues: The service queues managed by the social module are supported by additional structures to the existing ones in Asterisk/Elastix, given the peculiarity of the attributes that are stored in them, that are far from those handled in the telephony field. That is, they store messages processed by the processing module that will be consumed by the available agents. For this, they exploit the benefits of the RabbitMQ message broker, to make routing, persistency and handling of the messages that are delivered through the API of the social module.

Two routers are used to deliver the messages to four different queue structures that have configurations that enable specific persistence functionalities and work mode (ACK waiting). Each of these queues represents a different flow over the complete system, since each message has specific information, that is, each one receives specific data depending on the type of messages in which it was categorized by the processing module, according to the request generated by the client.

There is a one-to-one correspondence between the type of message and the routing key that each queue has inside RabbitMQ, which is an integer between 0 and 3, representing complaints, doubts by calls, doubts by direct messages, and compliments, respectively. Likewise, there is an additional queue managed by an alternate router, which was implemented for reasons of future expansion and to cover the loss of any user message that is routed with a different "key route," than the one known within the solution.

3) Call Center Module: The Elastix Call Center module is designed to handle incoming and outgoing call campaigns, allowing the interaction between agents and telephone service subscribers. For the purpose of integration with social networks, the messages found in the different queues of RabbitMQ that correspond to the incoming campaigns and the outgoing campaigns are used when scheduling a call. In this scheme, the customer is within the Elastix environment, specifically in the agent console, where a panel was developed where all the requests associated with Twitter and the users affiliated to the organization must appear.

4) Social Panel: Given the nature of the agent console to provide customer service through telephone calls, in the development of the social panel, different types of responses were enabled that agents can use to solve the requests obtained from the social network. In our case, the answers are handled through direct messages to users, or a call is planned to them. In the social panel, there is a button called "Enable Social Media" to enable the process of consumption of messages in RabbitMQ. When activated, a series of flows that are explained below are triggered:

1. Instantiation of a RabbitMQ consumer.
2. Acquisition of messages from the queues subscribed by the consumer.
3. Visualization of the information of the messages in the agent console (Social Panel).
4. Change of the displayed labels in certain buttons of the view.
5. Initialization of two timers for the attention of each instance of an active agent console.

Figure 6 depicts the agent console with the Social Panel activated.

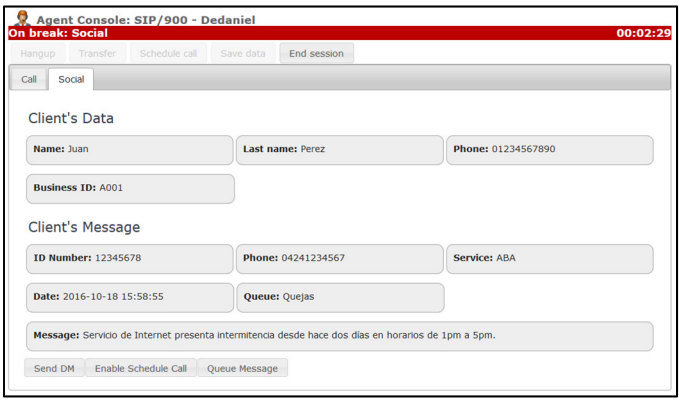

Figure 6: Agent Console – Social Panel

The operation mode of the social panel is cyclical. When the social mode is activated, a message is consumed from the service queues of RabbitMQ. The agent console takes care of it, and finally an intermediate time of action is given before the next message is consumed.

VI. Tests and Particular Situations

Table I describes the set of tests associated with performance and load, which were done to determine the impact of the social module on the Elastix communications server. In this way, we were looking to evaluate and determine if the implementation of this module is feasible on a production environment in terms of response times so that it can be used in a real customer service. To carry out the tests, we used PHPUnit, a well-known PHP framework for testing. With PHPUnit, users can adjust the values according to the scenario of each test, depending on the requirement to be evaluated.

Table I: Description of the Tests

ID	Name	Description
1	Processing Direct Messages	Determine the average time and the impact of processing direct messages obtained in the PM (Processing Module) from the Twitter API.
2	Submitting Direct Messages	Determine the average time and the behavior of the application when generating a direct message from the agent console.
3	Retrieving Direct Messages	Determine the average time and the impact when retrieving the direct messages sent to the associated account of the application.

VII. Performance Validation of our Proposal

A. *Time for Processing Direct Messages*

The purpose of this test is to determine the average time which elapses between the acquisition of a message from the processing module, until it is sent to its respective service queue.

For this experiment, we generated 50 messages from the social network to the different service queues: 20 associated with the complaint queue, 20 for the doubt queue, and 10 for the congratulation queue. Figure 7 depicts the results that we obtained. The x-axis represents the experiment number (from 1 to 50), while the y-axis is the elapsed time in milliseconds. Our experimental results show that the elapsed time is acceptable for most of the experiments, that is, with a value under 2000 ms. The picks are due to high network traffic and load between our testbed and the Twitter servers, which are related to the Internet services.

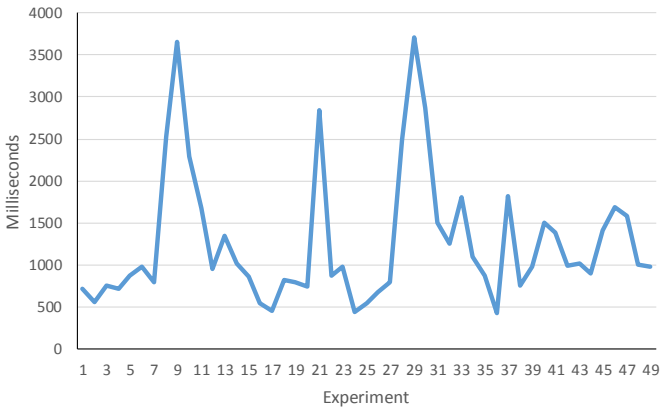

Figure 7: Response Times when Processing Direct Messages

B. *Time for Submitting Direct Messages*

The goal of this test was to evaluate the effective time to get and consume the web service of the processing module, which is responsible for sending direct messages to Twitter users, specifically those who have been answered from an instance of the agent console.

For this experiment, we generated 50 responses from the agent console to the 50 messages obtained from the service queues of the previous experiment. Figure 8 shows the results that we obtained. The x-axis represents the experiment number (from 1 to 50), while the y-axis is the response time in milliseconds. Our empirical results show a response time that is acceptable for most of the experiments, that is, with a value under 1500 ms. It is worth remembering that this time should be lower than in the previous experiment, since the consumption was directly against the processing module, and not against the service queues.

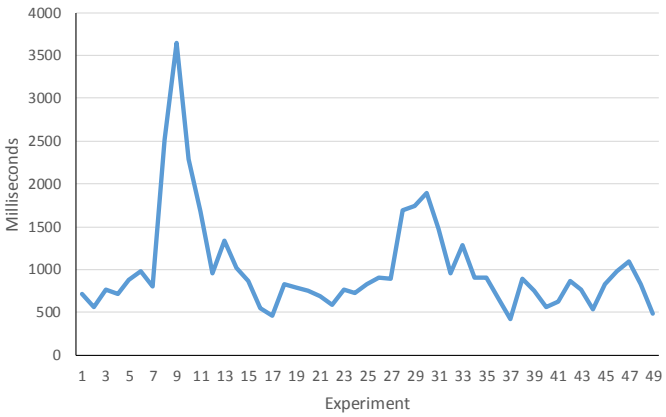

Figure 8: Response Times when Submitting Direct Messages

C. *Time for Retrieving Direct Messages*

The objective of this test was to determine the average time required by the Processing Module to retrieve all direct messages from the social network, that is, the time that elapses between a request sent by the Processing Module to Twitter to obtain all direct messages associated with a specific user account, and the reception of those. To do so, we generated 50

requests from the Processing Module to the social network (Twitter) to obtain the direct messages associated with the @SocialMedia_App account.

Figure 9 shows the results that we obtained. The x-axis represents the experiment number (from 1 to 50), while the y-axis is the response time in milliseconds. Our empirical results show a response time that is acceptable for most of the experiments, that is, with a value under 1000 ms. It is worth remembering that the value of this experiment will mainly depend on the network infrastructure and load between our testbed and the Twitter servers, which are bounded to the Internet services.

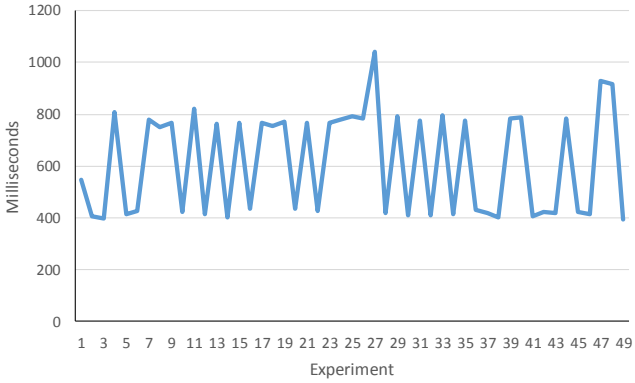

Figure 9: Response Time when Retrieving all the Direct Messages from a Specific Account in Twitter

VIII. Conclusions and Future Work

The usage of new technologies has increased exponentially with the rise of the Internet services. In the field of telephony, the classical telephony system, with its own network, is gradually replaced by VoIP, since it can use the existing data network (resulting in cost cut), and it allows a high degree of flexibility when developing custom applications.

Although unified communications systems and social networks have been around for some time, their possible integration has not been fully explored or exploited. In this research work, we proposed a solution that combines these two technologies together, to expand the communication channels offered to clients, for the customer service of an organization, by adding social networks as a new possible channel, to the range of tools currently offered by state-of-the-art telephone systems.

We are very interested in pursuing our work in this field. Since just a few researchers have been working in this direction, there are many open possibilities to enhance the area, and we are planning to explore the following ones:

- Transform the processing module into a backoffice, to have a simple and configurable interface.
- Develop a social network module where configurations can be made directly within Elastix, allowing the administration of outbound campaigns through direct messages or tweets to several customers using configurable templates.
- Produce predesigned templates to be used by the agent console when sending direct messages.
- Develop a statistics generator with a simple interface in terms of attended requests and their response times.
- Add artificial intelligence in the processing of messages, to train the system to identify negative words or phrases.
- Integrate some processes for data mining to know more about the organization's customers, with the goal of customizing outgoing campaigns.
- Port our development to Issabel [36][37], a fork of Elastix, maintained by the Internet community.

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An Approach to Evaluate Network Simulators: An Experience with Packet Tracer

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Abstract: Besides the measurement and the mathematical analysis, network simulation is a widespread methodology that is used to study computer systems and display their different aspects. However, a simulator is only an approximate model of the desired setting, leading to the need of establishing guidelines that support researchers in the tasks of selecting and customizing a simulator to suit their preferences and needs. In this paper, we propose a simple approach, based on a set of criteria for the evaluation and selection of network simulators, the implementation of the approach leads to results that are measurable and comparable. Then, the proposed approach was put to the test on Packet Tracer. The obtained results give a comprehensive overview of the simulator's features, its advantages, and disadvantages. This paper does not propose a method for selecting the best simulator, but it provides researchers with an evaluation tool that can be used to describe and compare network simulators in order to select the most appropriate one for a given scenario.

Keywords: Network Simulators; Evaluation Criteria; Comparison Approach; Packet Tracer.

I. Introduction

Network simulation is one of the most powerful and predominant evaluation methodologies in the area of computer networks. It is widely used for the development of new communication architectures and network protocols, as well as for verifying, managing, and predicting their behavior. Network simulators have grown in maturity since they first appeared and they have become an essential tool of the research domain, for both wired [1] and wireless networks [2].

Simulators are easy to control, save efforts in terms of time and cost, and allow repeating the same experiment with input changes. However, they are only an approximate model of the desired setting. Although the simulator is capable of simulating the whole network model, it is not possible to cover all of its aspects with the same level of details. Instead, the simulator focuses on one or two of the following aspects [3]: algorithms, application protocols, network protocols, and hardware. Then, the simulator fills the gaps in the other aspects using assumptions [4]. Hence, more studies are needed to establish guidelines that support researchers in the tasks of selecting and customizing a simulator to suit their preferences and needs.

A set of simulator design principles [5] were developed in the mid and late nineties. They meant to address main performance topics such as the balance issues between the execution time and accuracy, and how this issues can affect the simulation of nodes, links, and loads. In addition to that, simulators developers emphasize the concept of Validation, Verification, and Accreditation (VVA) [6], which was adopted by United States Department of defense as a principle method for modeling and simulation [7]. These principles and concepts described the design of simulators accurately, they led to the emergence of dozens of simulators in the next few years. Nowadays, there is a considerable number of simulations tools, in the market and freely available, that are distinguished, either for quality characteristics, such as accuracy, speed, ease of use, and monetary expense or by the capacity of modeling. As a result, selecting the simulator, that fits a given scenario the most, becomes a complex problem due to the variety of parameters to consider and the lack of clear methodology to follow.

One of the main motivation of this paper is to address this lack of guidelines. We propose a simple approach, based on a set of criteria to cover aspects related to the simulation process, as well as aspects related to the evaluation of the network simulator. Our criteria include ten items that can be applied to different network simulators in order to obtain a measurable and comparable assessment. We do not pretend that our approach is a methodology that identifies the best network simulator, as there are varieties of parameters and different possible network scenarios to adequately address that. Instead, this paper demonstrates how the suitability of simulators can be validated for particular needs, following an approach comprised by simple steps and based on a set of

criteria.

To illustrate the applicability of our proposed approach, we evaluate Packet Tracer, it is a simulation tool for both wired and wireless networks. Moreover, it can be used to build complex topologies that simultaneously run different protocols, thus, it is a powerful tool to implement complex and inter-protocols scenarios [8]. Packet Tracer allows the simulation of Cisco's IOS with a high degree of accuracy. It also allows simulating other information systems, such as servers and terminals, as well as some concepts of Internet Of Things (IoT), but with a high level of abstractions, [9]. The simulator has an attractive customizable graphical user interface (GUI) and allows contribution for multi-users activities [10].

The initial studies that mentioned Packet Tracer were limited to the educational aspects, but with the development of the simulator, new studies start taking place in many technical fields. However, there is no specific or comprehensive study for the simulator itself or for its features. In total, the simulator is not a considerable option for researchers in network domains. Hence, we demonstrate that if it is properly evaluated, it becomes an available option for researchers to pursue in their studies.

In summary the contribution of this work is twofold:

1) Propose an approach and a set of criteria to evaluate network simulators; and
2) Evaluate Packet Tracer features, performance, advantages, and disadvantages based on the criteria previously proposed, to show its suitability for researchers in network domains.

The remainder of this paper is organized as follows. In Section II, we survey recent works focused on proposing criteria or methodologies to evaluate network simulators and studies that have evaluated Packet Tracer simulator. Our proposed approach is described in Section III. How the methodology works, is illustrated in Section IV by evaluating Packet Tracer. We draw some recommendations based on the results. Finally, Section V highlights conclusions and perspectives.

II. Related Work

In this section we present two separate surveys, first, we survey studies focused on proposing methods and criteria to evaluate network simulators, and then we provide works that have evaluated Packet Tracer. We highlight their limitations and differences compared with our proposal.

A. Network Simulators Evaluation

The Virtual InterNetwork Testbed (VINT) Project [11] intended to develop methods and tools to address the scale and heterogeneity of the Internet protocols. One important result of the work was adding definitions related to the simulation issues, including the type and the nature of simulators, in addition to highlighting different interactions of the simulated protocols. In [12], there was another attempt to address the issues that concern the simulators developers concluded that there are four of them, namely the type of problem, the level of abstraction, the extensibility, and the diagnosis of existing codes. Later, a detailed and comprehensive study [13] recognized modeling as a foundation stone in the choices of simulators.

In [14], nine evaluation criteria are proposed to evaluate wireless sensor networks. Some of them have been incorporated in our set of criteria. Some other works propose the evaluation of simulators in terms of computational run time, memory usage, and scalability [3][15][16][17][18].

Even though these works propose some aspects that should be taken into account to evaluate simulators, none of them propose a coherent and complete method to do the evaluation, neither evaluate Packet Tracer, as we do.

B. Packet Tracer Evaluation

A variety of studies evaluated one or more different aspects of Packet Tracer. Authors in [19] used Packet Tracer, as well as another network simulator called GNS, to study the traffic in networks that support both IPv4 and IPv6, either using the dual stack technique or the tunneling. As a result, the article concludes that Packet Tracer is "easy to use", but it does not simulate all services and functions like tunneling. On the other hand, in [20], the problem of support for tunneling in Packet Tracer was addressed. In their study, GRE tunnels were properly simulated in addition to many IPsec features. This is a good example of the problem of lack of comprehensive studies. In fact, the tunneling feature was supported since the version 5.3, which was released in 2010.

In [21], a detailed study of the dynamic routing used Packet Tracer as a simulator. Four routing protocols were evaluated, they are Routing Information Protocol (RIP) (version 1 and 2), Open shortest path first (OSPF), and Enhanced Interior Gateway Routing Protocol (EIGRP). The article does not highlight on the simulator itself, thus, the simulation results were presented and discussed based on only the technical side of the network. A similar study that covers only RIPv2 and EIGRP can also be found in [22].

In [23], a performance study is presented based on a scenario implemented using Packet Tracer, The scenario covers both IPv4 and IPv6 networks. The study focuses on the delay, routing traffic, and convergence when OSPF and EIGRP are used. In the end, the authors concluded that Packet Tracer is a useful tool for routing studies, especially to select a routing protocol and to design the optimal routing topology based on that.

A comprehensive study of the Link Layer technologies and protocols can be found in [24]. Trunk ports, static Virtual Local Area Networks (VLANs), Dynamic VLANs, Inter-Switch Link (ISL), and IEEE 802.1Q were tested and verified. In addition to that, the authors implement a scenario using both OSPF as a routing protocol, Dynamic Host Configuration Protocol (DHCP) as a client/service protocol, and access lists as a security application. Packet Tracer was able to simulate the network and trace the packets when different-layers protocols were simultaneously used.

In [25], the use of the Packet Tracer as an assessment tool is discussed. The application has an advantage that it allows the user to stop the simulation at a given moment and check all the messages exchanged among different network nodes. The author concludes that although the simulator was not primarily designed as an assessment and measurement tool, it can use to aid certain educational purpose. The use of the Packet Tracer as an assessment tool is related to the nature of the study, while it does not appear to be used in performance studies, such a tool can add a benefit in the studies of the routing protocols.

Finally, there is a comparison study that mentioned 12 comparative items between GNS3 and Packet Tracer [26]. The items are: the GUI design, the memory requirement, the hardware models supported, the protocol supported, the commands supported, the computer systems supported, the ability to analyse traffic, the ability to exchange the topology, the types of connection supported, the certifications that use the simulators, the license, and the support for the instructor. Although [26] covers many aspects of Packet Tracer, it addresses the aspects from the comparison point of view, without considering the simulator's own capabilities or its maximum limits. In addition, this study does not include items for the performance of the simulator. Instead, it only mentions the minimum memory requirements. Finally, the authors insist on providing results rather than developing a coherent methodology, that, in turn, makes it intended for students and teachers more than researchers.

There are other studies that are interested in the simulator as an e-learning tool [27][28], but that is out of the scope of this article.

III. Evaluation Approach and Criteria

In this section, we explain how we address the problem of evaluating network simulators. First, we describe the proposed evaluation approach, then, we provide, in detail, a list of ten criteria to be used as measurements for the evaluation.

A. Evaluation Approach

As far as we know, there is no fixed approach or methodology to evaluate network simulators. As long as the developing of simulators continues, any methodology will remain subject to modernization and modification [29]. Thus, we do not pretend to establish a methodology, instead, we propose a single approach based on few steps and a set of criteria to demonstrate how the suitability of simulators can be validated for particular needs. The primary objective of the development of this approach is to evaluate qualitative aspects, as well as to obtain measurable or comparable values after applying the approach to a network simulator to describe its behavior, capacity, and performance.

Hence, to evaluate simulators, we propose to follow the following steps:

1) Establish a set of criteria. The evaluation of the simulator requires clear and accurate criteria to assess the different aspects of the simulator. Qualitative criteria can be described by a word or number, while quantitative criteria need to be measured. Moreover, there can exit composite parameters, that are composed of multiple sub-parameters. In the next section, we provide precise and specific definitions of ten parameters that describe and evaluate simulators from different qualitative and quantitative aspects.
2) Establish the experiment setup. It is worthy to install the selected simulator(s) on different systems (e.g., Windows, Linux, MacOS) under the same architecture. The way that operating systems manage system resources and the produced overhead have an important impact on the behavior of applications.
3) Evaluate the qualitative criteria of the simulator(s). Revise the available documentation of simulator(s) and elaborate a table highlighting their characteristics.
4) Design a test scenario to evaluate the measurable criteria. Decide the network elements that will be simulated according to the protocols that are intended to evaluate. Define the number and type of experiments, as well as the time of the simulation, taking into account the criteria to be evaluated.
5) Evaluate the measurable criteria of the simulator(s) by executing the designed experiments. Elaborate tables and graphics to show the results in order to facilitate the analysis and comparison (if there is a case).
6) Elaborate a discussion by analyzing the results.

These steps can be applied to evaluate a single simulator or to compare several of them.

B. Criteria

The following parameters will be used to evaluate the simulator, a detailed and precise definition is provided for each of them.

1) **Nature of the software:** The simulation consists of a number of models that are executed to interact with each other. The nature of the simulation is an assessment of how the simulation is performed. Precisely, the use of the word *simulation* means that the entire process is programmed, it is a software. But if the word *emulation* is used, the hardware is involved in the process [30].
2) **Type of the software:** It is a characterization of the philosophy underlying the simulator's work. Network simulations are based on two philosophies, a simulator is either a discrete-event simulator or trace-driven one. In the first, an initial set of events is generated, it represents the initial conditions. Those conditions, in turn, generate another set of events, the process continues like that, until the end of the simulation.
   In the trace-driven simulation, all events to be simulated are added to the simulator in the form of inputs, thus, it can simulate it and trace the outputs [31].
3) **License:** An evaluation of the capability to use the simulator from a legal aspect, simulators can be private property or they can be developed under a free or public agreement.

4) **User interface:** An evaluation of how can a user interact with the simulator, this includes two aspects:
   - Graphical User Interface (GUI): an evaluation of the support for the graphic interface. Is it an integral part of the simulator? what are the level of details it can show ?
   - Supported programing languages.
5) **Supported platforms:** It is the characterization of the usability of the simulators source code on different platforms and operating systems [32].
6) **Heterogeneity:** An evaluation of the ability to simulate heterogeneous systems where different types of nodes can exist in the same scenario [33].
7) **Modeling:** An evaluation of the ability to modify existing models or to implement and test new ones.
8) **Level of details:** An evaluation of the level of aspects that are being simulated. Those aspects, sorted in descending order, are: abstract algorithms, high level protocols, low-level protocols, and hardware. The lower the level, the less the assumptions and the more the constraints [14].
9) **Supported technology and protocols:** In order to evaluate the support provided for the protocols, TCP/IP model is used [34]. It is a 4-layer stack model, that classifies the network protocols, features, and services according to the function. Starting from the top, these layers are: application, transport, Internet, and link layers.
   We have excluded the routing protocols from this stack and combined them into a single item. The reason behind this is the distribution of the routing protocols in the layers of the model, this does not serve the primary purpose of this item, namely the assessment of support to the protocols.
10) **Performance:** The main purpose of the study of performance is to provide a general idea of the effectiveness of the simulator in terms of implementation time and the consumption of available resources. However, the proposed approach includes three factors for the performance study:
    - CPU Utilization: it is a measure of the application performance [35], it is the percentage of time spent performing the applications processes of the total processing time [36], i.e., the percentage of the processor cycles that are consumed by the applications processes.
    - Execution time: it is the time needed to complete a simulated scenario; measured in seconds.
    - Memory usage: it is the amount of memory used by the application, measured in bytes.

In the next section, we apply the approach to evaluate Packet Tracer.

IV. Applying the Approach

This section is dedicated to the practical aspect, in which we apply the proposed approach to evaluate Packet Tracer. In the following, we describe how the proposed steps and set of evaluation criteria are considered to evaluate Packet Tracer simulator. At the end, we discuss about the suitability of our proposed approach.

A. Step 1: Establish a Set of Criteria

Following the proposed approach leads to a 10-items description for the simulator. The considered set of evaluation criteria is the one presented in Section III-B.

B. Step 2: Establish the Experiment Setup

In order to apply the proposed criteria, we installed the simulator on two different systems, namely Linux Ubuntu 16.04 LTS and Microsoft Windows 10 version 10.0.14393. Both were installed on the same computer with the following characteristics: Intel(R) Core(TM) i7-7500U CPU @ 2.70GHz with 16 GB for the RAM, 915 GB of the hard disk is allocated for Linux while 909 GB is allocated for Windows.

C. Step 3: Evaluate the Qualitative Criteria

After the installation, nine of the evaluation criteria can be pointed out, according to the documentation and general knowledge about Packet Tracer. Only the performance criterion requires special scenario preparation. Table I shows the result of this step.

Some of the information presented in Table I was directly obtained from the official website of Packet Tracer, such as supported platforms. Others, like the supported technologies and protocols, required running the simulator to test and verify whether the support exists.

D. Step 4: Design the Test Scenario

We designed a scenario involving several experiments, in which we used the Spanning Tree Protocol (STP) to measure performance determinants. Originally, the STP is used in a layer 2 switched environment to create a loop-free path to data traffic. By default, the protocol convergence time is between 20 to 55 seconds. Several factors can affect the exact value, including the network complexity and the timers values. To consider that, we established the duration of each experiment in 60 seconds, while the convergence time is the time needed for the protocol to converge.

The scenario is built in a way that reflects the CPU utilization and memory usage. To achieve that, we adopted a meshed topology, whose size is increasing exponentially every time we are repeating the test. The basic component of the topology consists of four 2960 Cisco Catalyst switches arranged in a ring topology. Figure 1(a) shows the ring topology of the basic component, which is the scenario of the first test. Then, the second test is done with two basic components, i.e., eight switches, as shown in Figure 1(b). The third one is composed by four basic components, with 16 switches (see Figure 1(c)), and so on increasing the number of basic components exponentially with base 2, until 64 basic components, with 256 switches. In total, we conducted seven tests with 1, 2, 4, 8, 16, 32, and 64 basic components, on each system (Linux and Windows).

Table I: Nine Qualitative Criteria of Packet Tracer

Criteria	Packet Tracer Characteristic
Nature of the software	Simulator
Type of the software	Discrete-event
License	Proprietary, but an End User License Agreement (EULA) exists
User Interface	**GUI:** Yes a built-in GUI interface is supported, with a possibility to trace and store all events. Different languages are supported for the GUI including: English, Russian, German, Portuguese, Spanish and French. **Supported programing language**: Non, it is private property, but scripting is allowed using the Cisco IOS Syntax.
Platform	Linux, Android 4.1+, iOS 8+ and Microsoft Windows.
Heterogeneity	It is supported, different types of real **routers**, such as: Cisco 1941, Cisco 2901, Cisco 2911, and others are supported, as well as different types of real **switches** like: Cisco Catalyst 2950, Cisco Catalyst 2960, Cisco Catalyst 3560-24PS are supported. In addition to that, Linksys WRT300N **wireless router**, Cisco 2504 **wireless controller**, and Cisco Aironet 3700 **access point** are supported. Cisco ASA 5505 **firewall** is supported as well. Variety of IoT devices are supported.
Modeling	It is not supported.
Level of details	Packet level.
Supported technology and protocols	**Application Layer:** Protocols: DHCP, DHCPv6, FTP, HTTP, HTTPS, RADIUS, POP3, SMTP, SNMP, SSH, Telnet, TACACS. Technology: Access Lists, DNS, IoT, IoT TCP, SYSLOG. **Transport Layer:** Protocols: SCCP, TCP, UDP. **Network Layer:** Protocols: ARP, CAPWAP, HSRP, HSRPv6, ICMP, ICMPv6, IP, IPv6, NDP. Technology: IPSec, Cisco NetFlow. **Link Layer**: Protocols: Bluetooth, CDP, CTP, H.323, LACP, LLDP, PAgP, STP, USB, VTP. **Routing Protocols:** BGP, EIGRP, EIGRPv6, OSPF, OSPFv6, RIP, RIPng,

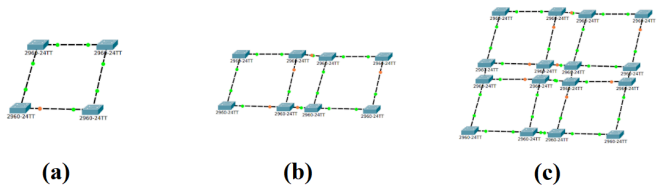

Figure 1: The Different Topologies Used in the Suggested Scenario, (a) A Basic Component Topology, (b) Two Basic Components Topology, (c) Four Basic Components Topology

E. Step 5: Evaluate the Measurable Criteria

Information related to nine of the ten evaluation criteria are shown in Table I, representing the qualitative criteria. The scenario depicted in the previous subsection, was designed to evaluate the performance in terms of CPU utilization, memory usage, and converge time (i.e., the time in which STP converges), which are measurable criteria.

To obtain the performance values in Linux, we used Monit[1], an open source tool for monitoring processes on Unix systems. For the tests in Windows, values were obtained from Task Manager, a built-in monitor of the CPU utilization and memory usage per process.

Figure 2 shows the results of all tests for CPU utilization, when the suggested scenario is implemented on Linux. Figure 3 shows the results for the same tests, when running the scenario on Windows. In both cases, we registered the percentage of CPU utilization every second during the simulation. Comparing both results tells that Windows is more suitable for the simulator in terms of CPU utilization.

Figure 4 displays a comparison of the memory usage for the same previous tests, for both operating system. We measured the percentage of memory usage of Packet Tracer at the beginning of each simulation test, i.e., the memory consumption is constant during the execution, there is no change.

[1]https://mmonit.com/monit

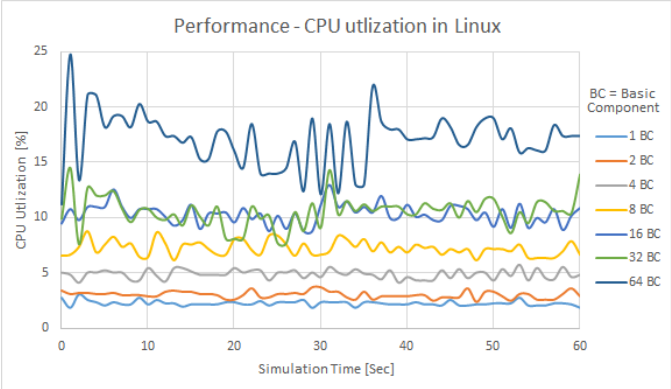

Figure 2: CPU Utilization - Linux

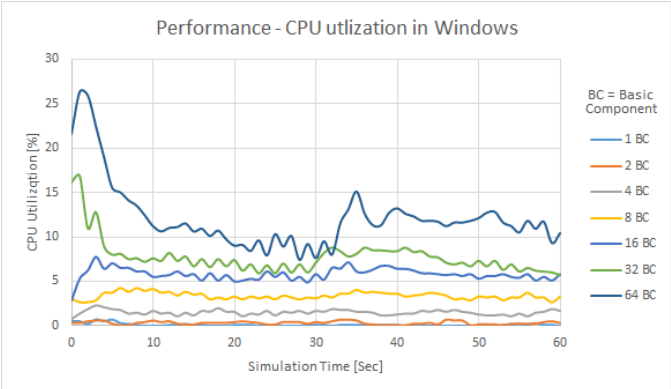

Figure 3: CPU Utilization - Windows

Since Packet Tracer is a discrete-event simulator, it generates a subsequence of events that are gathered in a buffer list, this buffer is overflowed when the number of the basic components is more than eight, We encountered the same problem both on Windows and Linux. Thus, it was not possible to obtain the convergence time of STP from tests whose topologies have more than eight basic components. However, Figure 5 shows the obtained results for the convergence time. As we note in Figure 5, results are similar in both Windows and Linux when

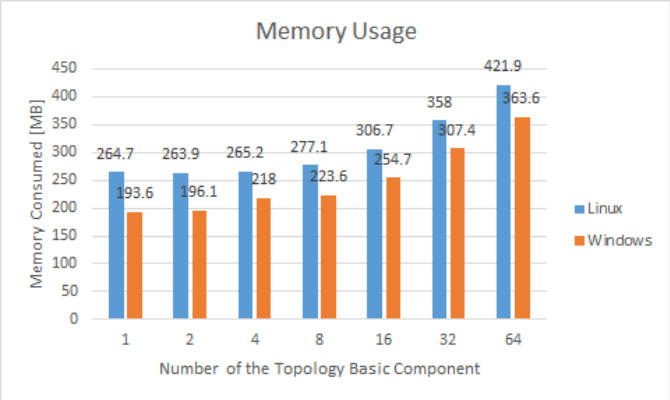

Figure 4: Memory Usage

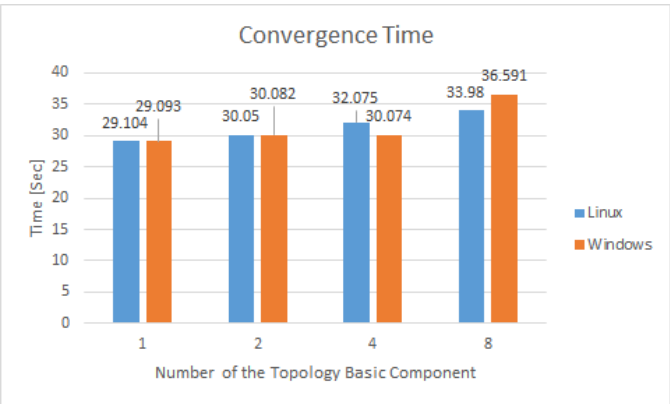

Figure 5: Converge Time

there are eight basic components or less.

F. Step 6: Elaborate a Discussion

In this section we present the analysis and discussion of the evaluation of Packet Tracer, derived from the obtained results.

Analyzing the qualitative criteria in Table I, we can say that Packet Tracer supports a wide variety of protocol in each layer, this gives the researchers multiple choices to create different scenarios. In addition to that, it provides the same GUI and functions on both Windows and Linux platforms.

We follow with the analysis of the measurable criteria. Regarding the CPU utilization, from Figure 2 and Figure 3, we can note that Packet Tracer behaves better in Windows than in Linux. In the beginning, we note that the CPU utilization for the topology that has one or two components is always around 1% for the tests in Windows, while the value rises to around 3% for the same tests done in Linux. For the topology of 16 basic components, the CPU utilization ratio is between 5-6% for Windows and 11-12% for Linux. Finally, the values of 64 basic components curve show a higher variance in the ratio more than all other curves, whether the tests were done in Windows or Linux. Results for all tests in Windows show a regular behavior, i.e., the more complex the topologies become, the higher the utilization of the CPU will be. The Linux results follow the same rule, except when the topology has 32 basic component, then, the behavior is irregular compared to the predictable one.

Concerning the memory usage, from Figure 4 we note that the change of values for memory usage shows an exponential form, both for the values obtained from Windows and Linux, this reflects the exponential change in the number of basic components as we change the input topology. In short, the memory used is directly related to the size of the topology in the scenario. Finally, in all the tests, the memory used by the simulator installed on Windows was better managed than the simulator installed on Linux.

From the evaluation of performance results, it was possible to detect one of the simulator disadvantages: the limit size of the events' buffer. Both, on Windows and Linux there was no way to have the exact converge time when the number of the basic components in the topology is more than eight.

In terms of performance characteristics, on one hand, the simulator uses the hardware more efficiently in Windows environment than in Linux, both on CPU utilization and memory usage parameters. On the other hand, the numbers of the execution time do not give us a clear image because it is limited to only 8 basic components.

Finally, even though Packet Tracer is a private simulator, its available version is good enough for simulating complex topologies from both Wide Area Network (WAN) and Local Area Network (LAN) aspects. It does not allow researchers to test new protocols or algorithms, but, it provides a massive set of protocols that can be used to create a large number of combinations of layered-protocols stacks.

G. Reflections about the Approach

The application of our proposed approach to evaluating Packet Tracer simulator, allow us to point out some reflections:

- A layered-protocols stack model is a powerful tool for categorizing the work done in the network by function, but there are some protocols that do not fit into a particular layer, that is because they perform functions belonging to more than one layer at the same time, examples of those protocols are the Neighbor Discovery Protocol (NDP) and Address Resolution Protocol (ARP), they both work on the Internet and Link layers, in this case, we categorize them in the upper layer, which is the network. Merging the technologies and protocols inside one criterion can become a complex issue if the simulator supports technologies that use more than one protocol, in different layers, this, in turn, will lead to a non-comparative item. In this case, it is better to separate technologies from protocols and by creating a new criterion. Then, the technologies item can have its own independent stack-layered model.
- The heterogeneity criterion needs to be described in more details, sub-criteria can be added based on further studies, the main goal is to enable the item to describe the simulator's ability to emulate different specific models or hardware.

- The study of performance characteristics shows that the simulator in Windows handles the hardware better than Linux in term of CPU utilization and memory usage, it is not possible to say that installing the simulator in Windows is better than Linux because there are other aspects of performance that have not been tested in this approach, such as scalability, which highlights different performance parameters that provides a more comprehensive view of The number of nodes that the simulator can simulate.
- We thought about adding a special criterion for the simulator version because it is an important piece of information, but it is related to each simulator itself, thus, it is not comparable among other simulators, that is why we did not consider the version as an item within the suggested approach.
- We are thinking of expanding the approach to include Wireless Sensor Network (WSN) simulators, but this requires further studies to modify the current approach or even developing an independent one. WSN requirements are different from those of wired ones. For example, mobility, environmental, energy consumption, energy harvesting, battery models, and others are specific-purpose concepts that are directly related to the nature of the WSN.

V. Conclusions

In this paper, we have addressed the difficulty of selecting a computer network simulator to fit a given scenario. To achieve that, we proposed an approach of ten criteria that can be applied to the simulator to describe it in a measurable and comparable manner.

In order to test how efficient the suggested approach is, we apply it on Cisco Packet Trace, which is a general-purpose network simulator. The application of the approach proved that it does not only highlight general aspects of the simulator's behavior but it showed its disadvantages as well.

In a future study, we plan to apply the approach to compare several network simulators and include other measurable criteria, such as scalability. We also are working on extending the proposed approach to consider Wireless Sensors Network (WSN) simulators, by involving special items describing the determinants of these networks, such as power constraints, models for energy consumption, and power harvesting.

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Índice de Autores

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