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Tecnura

Tecnología y cultura, afirmando el conocimiento

Universidad Distrital Francisco José de Caldas
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REVISTA TECNURA
La revista Tecnura es una publicación institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas de carácter científico-tecnológico, arbitrada mediante un proceso de revisión entre pares de doble ciego. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

PERIODICIDAD
Es una publicación de carácter científico-tecnológico con periodicidad trimestral, que se publica los meses de enero, abril, julio y octubre. Su primer número apareció en el segundo semestre del año 1997 y hasta la fecha ha mantenido su regularidad.

COBERTURA TEMÁTICA
Las áreas temáticas de interés de la revista Tecnura están enfocadas a todos los campos de la ingeniería, como la electrónica, telecomunicaciones, electricidad, sistemas, industrial, mecánica, catastral, civil, ambiental, entre otras. Sin embargo, no se restringe únicamente a estas, también tienen cabida los temas de educación y salud, siempre y cuando estén relacionados con la ingeniería. La revista publicará únicamente artículos de investigación científica y tecnológica, de reflexión y de revisión.

MISIÓN
La revista Tecnura tiene como misión divulgar resultados de proyectos de investigación realizados en el área de la ingeniería, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado.

PÚBLICO OBJETIVO
La revista Tecnura está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científico-tecnológica, en el campo de la ingeniería.

INDEXACIÓN
Tecnura es una publicación de carácter académico indexada en los indices regionales publindex indexada y clasificada en categoria B, Scielo Colombia y Redalyc (México); además de las siguientes bases bibliográficas: INSPEC del Institution of Engineering and Technology (Inglaterra), Fuente Académica Premier de EBSCO (Estados Unidos), CABI (Inglaterra), IndexCorpernicus (Polonia), Informe Académico de Gale Cengage Learning (México), Periódica de la Universidad Nacional Autónoma de México (México), Oceanet (España) y Dialnet de la Universidad de la Rioja (España); también hace parte de los siguientes directorios: Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, España y Portugal Latindex (México); Índice Bibliográfico Actualidad Iberoamericana (Chile), e-Revistas (España), DOAJ (Suecia), Ulrich de Proquest (Estados Unidos).

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TECNURA JOURNAL

Tecnura Journal is an institutional scientific-technological publication from the Faculty of Technology at District University Francisco José de Caldas, arbitrated by means of a double-blinded peer review process. The periodicity for its Scientific and Editorial committees line-up is subject to the publication of articles in internationally indexed magazines by its own members.

PERIODICITY

Tecnura journal is a scientific-technological publication with quarterly periodicity, published in January, April, July and October. Its first edition appeared in the second term, 1997 and its editions have normally continued from that year and on.

THEMATIC COVERAGE

The thematic areas of interest at Tecnura journal are focused on all fields of engineering such as electronical, telecommunications, electrical, computer, industrial, mechanical, cadastral, civil, environmental, etc. However, it is not restricted to those, there is also room for education and health topics as well, as long as they are related to engineering. The journal will only publish scientific and technological research, reflection and review articles.

MISSION

Tecnura journal is aimed at publishing research project results carried out in the field of engineering, through the publishing of original and unpublished articles written by academics and professionals from national or international public or private institutions.

TARGET AUDIENCE

Tecnura journal is directed to professors, researchers, students and professionals interested in permanent update of their knowledge and the monitoring of the scientific-technological research processes in the field of engineering.

INDEXING

Tecnura is an academic publication indexed in the Regional Index Scielo Colombia (Colombia) and Redalyc (México); as wel as the following bibliographic databases: INSPEC of the Institution of Engineering and Technology (England), Fuente Académica Premier of EBSCO (United States), CABI (England), Index Copernicus (Poland), Informe Académico of Gale Cengage Learning (México), Periódica of the Universidad Nacional Autónoma de México (México), Oceanet (Spain) and Dialnet of the Universidad de la Rioja (Spain); it is also part of the following directories: Online Regional Information System for Scientific journals from Latin America, Caribbean, Spain and Portugal Latindex (México), bibliographic index Actualidad Iberoamericana (Chile), e-Revistas (Spain), DOAJ (Sweden), Ulrich of Proquest (United States).

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https://revistas.udistrital.edu.co/index.php/Tecnura/about

El comité editorial de la revista **Tecnura** está comprometido con altos estándares de ética y buenas prácticas en la difusión y transferencia del conocimiento, para garantizar el rigor y la calidad científica. Es por ello que ha adoptado como referencia el Código de Conducta que, para editores de revistas científicas, ha establecido el Comité de Ética de Publicaciones (COPE: Committee on Publication Ethics) dentro de los cuales se destaca:

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En su calidad de máximos responsables de la revista, el comité y el equipo editorial de Tecnura se comprometen a:

- Aunar esfuerzos para satisfacer las necesidades de los lectores y autores.
- Propender por el mejoramiento continuo de la revista.
- Asegurar la calidad del material que se publica.
- Velar por la libertad de expresión.
- Mantener la integridad académica de su contenido.
- Impedir que intereses comerciales comprometan los criterios intelectuales.
- Publicar correcciones, aclaraciones, retractaciones y disculpas cuando sea necesario.

Relaciones con los lectores

Los lectores estarán informados acerca de quién ha financiado la investigación y sobre su papel en la investigación.

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Tecnura se compromete a asegurar la calidad del material que publica, informando sobre los objetivos y normas de la revista. Las decisiones de los editores para aceptar o rechazar un documento para su publicación se basan únicamente en la relevancia del trabajo, su originalidad y la pertinencia del estudio con relación a la línea editorial de la revista. La revista incluye una descripción de los procesos seguidos en la evaluación por pares de cada trabajo recibido. Cuenta con una guía de autores en la que se presenta esta información. Dicha guía se actualiza regularmente y contiene un vínculo a la presente declaración ética. Se reconoce el derecho de los autores a apelar las decisiones editoriales. Los editores no modificarán su decisión en la aceptación de envíos, a menos que se detecten irregularidades o situaciones extraordinarias. Cualquier cambio en los miembros del equipo editorial no afectará las decisiones ya tomadas, salvo casos excepcionales en los que confluyan graves circunstancias.

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Tecnura pone a disposición de los evaluadores una guía acerca de lo que se espera de ellos. La identidad de los evaluadores se encuentra en todo momento protegida, garantizando su anonimato.

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Tecnura garantiza que el material remitido para su publicación será considerado como materia reservada y confidencial mientras que se evalúa (doble ciego).

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Tecnura garantiza la confidencialidad de la información individual (por ejemplo, de los profesores y/o alumnos participantes como colaboradores o sujetos de estudio en las investigaciones presentadas).

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Cada vez que se tenga constancia de que algún trabajo publicado contiene inexactitudes importantes, declaraciones engañosas o distorsionadas, debe ser corregido de forma inmediata.
En caso de detectarse algún trabajo cuyo contenido sea fraudulento, será retirado tan pronto como se conozca, informando inmediatamente tanto a los lectores como a los sistemas de indexación.
Se consideran prácticas inadmisibles, y como tal se denunciarán las siguientes: el envío simultáneo de un mismo trabajo a varias revistas, la publicación duplicada o con cambios irrelevantes o parafraseo del mismo trabajo, o la fragmentación artificial de un trabajo en varios artículos.

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Tecnura establecerá los mecanismos necesarios para evitar o resolver los posibles conflictos de intereses entre autores, evaluadores y/o el propio equipo editorial.

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Cualquier autor, lector, evaluador o editor puede remitir sus quejas a los organismos competentes

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https://revistas.udistrital.edu.co/index.php/Tecnura/about

The editorial board of Tecnura journal is committed to ethics high standards and good practice for knowledge dissemination and transfer, in order to ensure rigour and scientific quality. That is why it has taken as reference the Code of Conduct, which has been established by the Committee on Publication Ethics (COPE) for scientific journal editors; outlining the following:

General duties and responsibilities of the editorial board

As most responsible for the journal, **Tecnura** committee and the editorial board are committed to:

- Joining efforts to meet the readers and authors' needs.
- Tending to the continuous improvement of the Journal.
- Ensuring quality of published material.
- Ensuring freedom of expression.
- Maintaining the academic integrity of their content.
- Prevent commercial interests compromise intellectual standards.
- Post corrections, clarifications, retractions and apologies when necessary.
- Relations with readers.
- Readers will be informed about who has funded re- search and their role in the research.

Relations with authors

Tecnura is committed to ensuring the quality of published material, informing the goals and standards of the journal. The decisions of publishers to accept or reject a paper for publication are based solely on the relevance of the work, originality and pertinence of the study with journal editorial line. The journal includes a description of the process for peer evaluation of each received work, and has an authors guide with this information. The guide is regularly updated and contains a link to this code of ethics. The journal recognizes the right of authors to appeal editorial decisions Publishers will not change their decision in accepting or rejecting articles, unless extraordinary circumstances or irregularities are detected. Any change in the editorial board members will not affect decisions already made, except for unusual cases where serious circumstances converge.

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Tecnura makes available to reviewers a guide to what is expected from them. Reviewers' identity is protected at all times, ensuring anonymity.

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Tecnura ensures that material submitted for publication will be considered private and confidential issue while being reviewed (double blind).

Claims

Tecnura is committed to respond quickly to complaints and ensure that dissatisfied claimant can process all complaints. In any case, if applicants fail to satisfy their claims, the journal considers that they have the right to raise their protests to other instances.

Promoting Academic Integrity

Tecnura ensures that the published material conforms to internationally accepted ethical standards.

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Tecnura guarantees the confidentiality of individual information (e.g. participant teachers and/or students as collaborators or subjects of study in the presented research).

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Tecnura accepts the obligation to act accordingly in case of suspected malpractice or misconduct. This obligation extends both to publish and unpublished documents. The editors not only reject manuscripts with doubts about possible misconduct, but they are considered ethically obligated to report suspected cases of misconduct. From the journal every reasonable effort is made to ensure that works submitted for evaluation are rigorous and ethically appropriate.

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Whenever evidence that a published work contains significant misstatements, misleading or distorted statements, it must be corrected immediately.
In case of any work with fraudulent content is detected, it will be removed as soon as it is known, and immediately informing both readers and indexing systems.
Practices that are considered unacceptable and as such will be reported: simultaneous sending of the same work to various journals, duplicate publication with irrelevant changes or paraphrase of the same work, or the artificial fragmentation of a work in several articles.

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The relation between editors, publishers and owners will be subject to the principle of editorial independence. **Tecnura** will ensure that articles are published based on their quality and suitability for readers, and not for an economic or political gain. In this sense, the fact that the journal is not governed by economic interests, and defends the ideal of universal and free access to knowledge, provides that independence.

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Editorial

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One of the greatest challenges that modern society is now facing is the climate change and this phenomenon constitutes an important task of the technology. Almost all opinion sectors around the world recognize that it is a real serious problem, which will have serious impacts on human lives, and all countries should take concrete actions.

According to some scenarios evaluated, if relevant actions are not taken to reduce greenhouse gases (GHG) emissions, towards the year 2035 global average temperature will increase above 2 °C, and at the end of this century it can exceed 5 °C.

The most exhaustive economic studies predict that overall costs and risks of climate change could imply a loss of 5 % to 20 % per year in global Gross Domestic Product (GDP); while costs to reduce GHG emissions to prevent climate change impacts can be limited to 1 % of global GDP each year.

Because impacts of climate change are a global problem with serious consequences in human life quality and environmental services, a global response is required. All countries will be affected, and in particular the poorest ones, where their population are more vulnerable to its effects, although paradoxically are the ones least contribute to this problem.

Climate change will affect the basic elements of people's life as potable water access, food production, health and safe environment. Extreme climates impacts will show costs of disasters such as droughts, storms, avalanches, etc.

Revised data show that climate change impacts can be reduced by stabilizing the atmosphere levels of GHG (CO_2) in 450 ppm to 550 ppm. Currently the average concentration is 430 ppm, but it is increasing 2 ppm every year. To stabilize these levels to reference values, the current GHG emissions must be reduced 89 %, given that the costs to reduce these levels are lower than the costs to face the impacts.

Actions on climate change can also generate business opportunities (technological changes, development of clean energy sources and new productive processes) that reduce the emissions growth. Besides pressure on ecosystems, deforestation and industrial processes intensive in fossil fuels use, must be reduced.

The problem magnitude requires definition and development of international policies with local application, to reduce emissions to acceptable range levels both in developed and developing countries. Some policies could be: taxes, trade, and carbon emissions price regulation, innovation and low-carbon technologies development, elimination of access barriers to new technologies, energy efficiency incentives, mass education strategies, communities and individuals persuasion about how they can face this situation, etc.

It is important to promote an international shared vision with long-term goals and build regulatory frameworks that help each country or region to achieve them. These frames can include concrete

actions on emissions trading that promote actual emissions reduction costs, technological cooperation, deforestation reduction and even adapting to new scenarios caused by climate change.

Cesar Augusto García-Ubaque
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Editorial

https://revistas.udistrital.edu.co/ojs/index.php/Tecnura/issue/view/1102

Uno de los grandes retos que afronta la sociedad moderna y por tanto para el quehacer de la tecnología es el cambio climático. Casi todos los sectores de opinión en el mundo entero, reconocen que es un problema serio, que tendrá graves impactos en la vida de los seres humanos y que por ello todos los países deben tomar acciones al respecto.

Según algunos de los diferentes escenarios evaluados, si no se toman medidas de fondo para reducir las emisiones de gases de efecto invernadero, hacia el año 2035 la temperatura promedio global se incrementará por encima de 2 °C y al finalizar el presente siglo puede exceder los 5 °C.

Los estudios económicos más exhaustivos predicen que los costos generales y los riesgos del cambio climático serán equivalentes a la pérdida de un 5 % del producto interno bruto global cada año, y que podría ascender a un 20 % o más; mientras que los costos de reducir la emisión de gases de efecto invernadero para evitar los impactos del cambio climático pueden limitarse a un 1 % del PIB global cada año.

Dado que los efectos del cambio climático constituyen un problema mundial, que tendrá serios impactos en la calidad de la vida humana y en los servicios ambientales, se requiere una respuesta de carácter global. Todos los países estarán afectados y de manera especial los más pobres ya que sus poblaciones son más vulnerables a sus efectos, aunque paradójicamente son los que menos contribuyen a este problema.

El cambio climático afectará elementos básicos de la vida de las personas como acceso al agua potable, producción de alimentos, salud y ambiente seguro entre otros. El impacto de los climas extremos se evidenciará en los costos que traerán consigo algunos desastres como avalanchas, sequías, tormentas, etc.

Las medidas estudiadas muestran que el impacto del cambio climático puede reducirse al estabilizar los niveles de gases de efecto invernadero en la atmósfera entre 450 ppm y 550 ppm de CO2. Actualmente la concentración promedio se encuentra en 430 ppm CO_2, pero se viene incrementando a una tasa de 2 ppm cada año. Para estabilizar estos niveles a los valores de referencia, se debe reducir en cerca del 89 % la emisión actual de estos gases, a sabiendas que el costo de las acciones para reducir estos niveles son más bajos que el costo que tendrá para la sociedad el no actuar.

Las acciones sobre el cambio climático también pueden generar oportunidades de negocio (cambios tecnológicos, desarrollo de energías alternativas y nuevos procesos productivos, entre otros) que reduzcan el crecimiento de esas emisiones. Así mismo debe reducirse la deforestación, la presión sobre los ecosistemas y los procesos industriales intensivos en uso de combustibles fósiles.

Dada la magnitud del problema, se hace necesario la definición y desarrollo de políticas internacionales con aplicación local para reducir las emisiones en los países desarrollados y en vía de desarrollo a niveles que estén en el rango aceptable. Entre estas políticas se pueden mencionar: impuestos, comercio y regulación del precio del carbono que se emite, innovación y desarrollo de tecnologías de

bajo carbono, eliminación de barreras al acceso a nuevas tecnologías, incentivos a la eficiencia energética, estrategias masivas de educación, persuasión a las comunidades e individuos acerca de lo que ellos pueden hacer frente esta problemática, etc.

Es importante promover una visión compartida a nivel internacional con metas de largo plazo y construir marcos regulatorios que ayuden a cada país o región a alcanzar estas metas. Estos marcos pueden incluir acciones concretas en comercio de emisiones con esquemas que promuevan la reducción en emisiones efectivas en costo, cooperación tecnológica, reducción de la deforestación e incluso adaptación a los nuevos escenarios ocasionados por el cambio climático.

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INVESTIGACIÓN

Monitoring Algorithm for Electrical Variables Implementing Blockchain and Python

Algoritmo de monitoreo de variables eléctricas implementando *blockchain* y Python

Javier Andres Muñoz-Romero [1], Diego Armando Giral-Ramírez [2], Carlos Alberto Ramírez-Vanegas [3]

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Abstract

Objective: This article presents a blockchain application in power systems using electrical variable monitoring delivered by a simulated relay.

Methodology: The electrical variables are verified, compared, and uploaded to a blockchain network created by a network of servers. These are responsible for uploading, validating, and exporting information to the algorithm. This study is carried out by means of the Python programming language.

Results: An algorithm capable of integrating these variables from a simulated relay is created, as well as four servers in charge of taking the relay signals every minute, validating that they are unique in the blockchain and uploading them. The first node that completes this task uploads its identification and the information of the relay. Once obtained, the information processing times are approximately 10 seconds.

Conclusions: It is concluded that the algorithm is capable of decentralizing the information collected by the servers in times equal to or greater than one minute, which can be very useful when saving information. In applications such as control by the network operator, it falls short by having times higher than or equal to one minute. It should be taken into account that, for the development of a blockchain with a greater number of equipment, it is advisable to use machines with high levels of processing and much greater RAMs. These characteristics would allow the algorithm to run smoothly and in the shortest time possible.

Financing: Universidad Distrital Francisco José de Caldas

Keywords: blockchain, GetChain, data mining, monitoring algorithm, electrical substation

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Resumen

Objetivo: Este artículo presenta una aplicación *blockchain* en sistemas de energía que emplea el monitoreo de variables eléctricas entregado por un relé simulado.
Metodología: Las variables eléctricas se verifican, comparan y cargan en una red *blockchain* creada por una red de servidores; estos son responsables de cargar, validar y exportar información al sistema. Este estudio se realiza a través del lenguaje de programación Python.
Resultados: Se crea un algoritmo capaz de integrar estas variables desde un relé simulado, así como 4 servidores que se encargan de tomar las señales del relé cada minuto, validando que son únicas en la *blockchain* y subiéndolas. El primer nodo que completa esta tarea carga su identificación y la información del relé. Una vez obtenida, los tiempos de procesamiento de la información son aproximadamente 10 segundos.
Conclusiones: Se concluye que el algoritmo es capaz de descentralizar la información recolectada por los servidores en tiempos iguales o mayores a un minuto, lo que puede ser de gran utilidad a la hora de guardar información. En aplicaciones como el control por parte del operador de red, se queda corto al tener tiempos mayores o iguales a un minuto. Se debe tener en cuenta que, para el desarrollo de una cadena de bloques con una mayor cantidad de equipos, es recomendable utilizar máquinas con altos niveles de procesamiento y memorias RAM mucho más grandes. Estas características permitirían que el algoritmo funcionara sin problemas y en el menor tiempo posible.
Financiamiento: Universidad Distrital Francisco José de Caldas

Palabras clave: blockchain, GetChain, minería de datos, sistema de monitoreo, subestación eléctrica

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INTRODUCTION

Currently, blockchain algorithms are used for the development of smart contracts and controlling digital currencies such as Bitcoin, among other applications, as the benefits of blockchain become more visible. In recent years, there was an exponential growth in the use of systems based on this technology (Pandey *et al.,* 2019). This type of algorithm allows maintaining greater security in the fulfillment of the so-called transactions. This algorithm also avoids information manipulation through the encryption offered by algorithms such as SHA256 and others, given that information is handled in a decentralized manner through a network of servers connected between them. These servers also control the same information and validate a new distribution made and added to the chain. A blockchain can handle data at a low cost, releasing it from intelligent devices to create economic value (Yu *et al.,* 2019).

General context

Over time, the demand for electricity supply grows more and more, so power systems need to have constant monitoring and also guarantee the users' energy quality. Ongoing monitoring, control, and event recording systems are centralized and monopolized (Alam *et al.,* 2019). Their structure includes a control center, which is responsible for monitoring and controlling the different variables in an electrical substation.

Over the past few years, prosumers (producer and consumer) have emerged, so microgrids have become popular with their bidirectional power supply configuration. However, current systems cannot manage, trade, and ensure the security of these systems. Alam *et al.,* 2019 propose a blockchain-based approach to address these challenges, where the algorithms attempt to implement smart contracts, mode coalitions, and negotiate electricity trade bidirectionally.

In the electronic power trading sector, the use of blockchain has several benefits, such as data integrity and the detection of any unauthorized intervention, elimination of monopoly at any stage of the market, transparency in the trading system, security and identity protection, and the facilitation of secure energy and credit transactions within the system (Alam *et al.,* 2019, N. Wang *et al.,* 2019).

Nowadays, blockchain technology has gained increased attention (Pava *et al.,* 2021). However, it still poses several technical challenges, such as scalability and security. Over time, these challenges

have been tested to strengthen the barriers against threats and system attacks (Leka *et al.,* 2019). Thus, the public-key infrastructure (PKI) that manages the blockchain is the basis and the core of building network security. Blockchain has many technical features, such as decentralization and the impossibility of being manipulated and forged (Foti *et al.,* 2021). These features increase the reliability in information, security, traceability, and other aspects of traditional technology (R. Wang *et al.,* 2019).

A blockchain contains a series of structures or data blocks. Here, the information is stored in an encrypted blockchain. Likewise, the data is distributed in a network by all the nodes (Pava *et al.,* 2021, Yang *et al.,* 2021). The data records are synchronized, which means they keep the same data throughout the network for each server. This means that data cannot be modified by one server without the authorization and validation of all other network administrators, thus making blockchain an immutable data management system. Moreover, any addition of information is verified (Alam *et al.,* 2019).

Therefore, end-users must supervise power systems according to their needs in order to guarantee the quality of the electric service and the authenticity of the information supplied by the grid operator.

Contributions and scope

The objective of the development of this algorithm is to show that energy service customers can perform system verifications, substation-occurring event validation, and constant monitoring of the algorithm. In addition, customers become watchdogs for the reports issued by the grid operator on power quality. The data are unlikely to be altered by third parties due to user participation in the network.

Literature review

There are many applications for blockchain networks in power systems. Below are three recently developed blockchain applications.

Pipattanasomporn *et al.,* 2018 created a blockchain-based platform that handles solar power exchange. The platform's implementation is, as the authors call it, "lab-scale". Their paper addresses a blockchain network application for solar electricity exchange between participants using Hyperledger, an open-source platform created by Linux. This application lists the participants, assets, and transactions needed to establish the blockchain-based network to track solar PV sales along with the smart contract, use cases, and implementation. According to the authors, there are several blockchain pilots in the energy sector. These pilots focus on commercial, legal, and financial aspects. However, there is no detailed knowledge on how to implement a blockchain-based trading platform.

Ai *et al.,* 2020 analyze the challenges of centralized energy charging in the traditional context, which do not apply to using the settlement of distributed energy transactions. The authors do this

to address the inconsistency issues with information in the microgrid, the difficulty in establishing a trust system, energy losses, and costs due to pre-sale. Likewise, this study proposes a blockchain-based asynchronous settlement system for microgrid energy transactions. Their experiments showed that this system solves the aforementioned problems well and meets the requirements of practical applications.

Hussain *et al.*, 2019 states that the use of blockchain technology for energy trading can eliminate the role of a third-party intermediary entrusted with energy billing. The authors also analyze the feasibility and benefits of using blockchain for smart grids. They developed an Ethereum-based application of blockchain technology for energy trading. They show how blockchain technology can be an excellent alternative to conventional cryptocurrency standards based on third-party trust. The results show that said technology can be successfully implemented to maintain a distributed database for transactions between customers and traders.

METHODOLOGY

This work attempts to integrate the most important measurement data and events delivered in an electrical substation by a relay to a blockchain. This substation is responsible for verifying data authenticity, mining the information, and validating the chain through the computers that make up the network. All the development work is conducted in the Python programming language. Figure **1** presents the flow diagram of the implemented methodology. Each of the stages of the methodology is described below.

Simulated relay data

First, a Python file is created which is responsible for simulating the average and event data commonly obtained from a relay. The Python file also displays the collected data date, the device name, the substation, the events recorded, and measurements such as phase voltage, line currents, frequency, power factor, and active and reactive power, all with their corresponding timestamp.

These events are captured with 10-second intervals between them. They are also stored in a plain text file every minute in a folder on a server. Figure **2** shows the results of the data. The algorithm implemented in the simulation is presented in Algorithm 1.

Internal chain update

A Python file is created for each server that connects to the network that will host the code and is responsible for the nodes' connection with the blockchain. This file will establish the data to be added along with the corresponding validation. As a first step, there will be a verification and internal

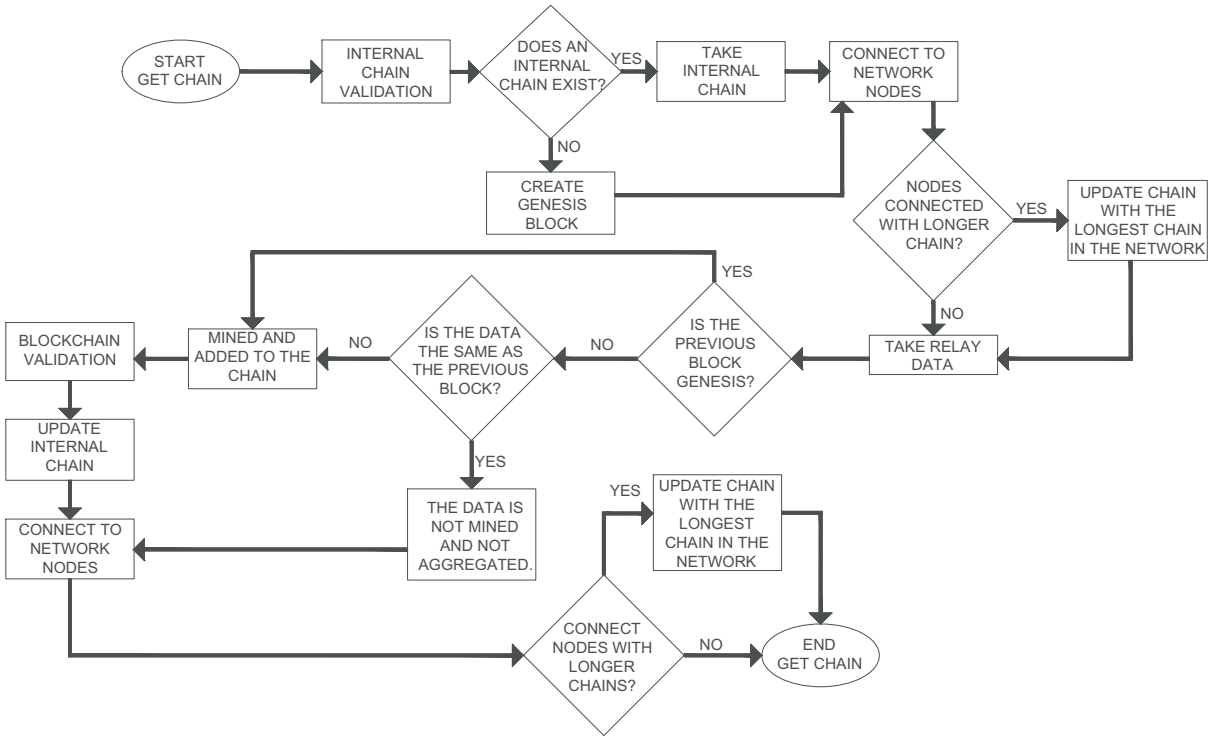

Figure 1. Algorithm development methodology

Source: Authors.

```
02 07 2021 18 11
Relay 1
Bogotá Electrical Substation - U.D.


Openings caused by faults: 22.0


Time Stamp;28 09 2021 07 01 18;Vab;115.314;Vbc;116.048;Vca;116.293;Ia;26.082;Ib;30.831;Ic;45.186;F;60.158;FP;0.979;P;236.887;Q;57.743
Time Stamp;28 09 2021 07 01 28;Vab;110.69;Vbc;117.149;Vca;112.374;Ia;41.868;Ib;41.825;Ic;26.057;F;59.877;FP;0.715;P;125.543;Q;615.162
Time Stamp;28 09 2021 07 01 38;Vab;114.175;Vbc;117.479;Vca;111.914;Ia;17.894;Ib;32.324;Ic;49.737;F;59.342;FP;0.513;P;595.397;Q;507.482
Time Stamp;28 09 2021 07 01 48;Vab;116.332;Vbc;113.905;Vca;115.683;Ia;44.307;Ib;0.065;Ic;29.083;F;59.067;FP;0.81;P;122.33;Q;486.381
Time Stamp;28 09 2021 07 01 58;Vab;112.672;Vbc;115.69;Vca;109.112;Ia;19.199;Ib;22.847;Ic;1.307;F;59.477;FP;0.998;P;155.695;Q;50.381
Time Stamp;28 09 2021 07 02 08;Vab;110.577;Vbc;112.259;Vca;112.543;Ia;37.693;Ib;12.535;Ic;29.003;F;60.857;FP;0.306;P;175.923;Q;392.21
```

Figure 2. Plain text data obtained by simulation of a relay simulation of a relay

Source: Authors.

update of the node blockchain cable. Then, programmed functions will update the blockchain data, such as its length. Finally, the algorithm will store the data.

Algorithm 1. Data simulation

#First Cicle
While K is greater than 1:
T_general = (current day, month, year, hour and minute)
We create a file called CAPTURING.txt
Header = (Relay name and Electrical Substation name)
Faults = (We indicate how many faults were generated in the last minute indicated by a random number between 0 and 28)
Finally, we write the value of the variable **"Header"** and **"Faults"** in the .TXT file.
#Second Cicle
While T_general is equal to T_date:
T_date = (current day, month, year, hour and minute)
#This guarantees that, when there is a time greater than one minute, the program stops.
Vab = Random value between 109 and 118 taking 3 decimal places
Vbc = Random value between 109 and 118 taking 3 decimal places
Vca = Random value between 109 and 118 taking 3 decimal places
Voltage = Vab, Vbc and **Vca**
Ia = Random value between 0 and 50 taking 3 decimal places
Ib = Random value between 0 and 50 taking 3 decimal places
Ic = Random value between 0 and 50 taking 3 decimal places
Current = Ia, Ib and **Ic**
Freq = Random value between 59 and 61 taking 3 decimal places
FP = Random value between 0 and 1 taking 3 decimal places
Pt = Random value between 0 and 700 taking 3 decimal places
Qt = Random value between 0 and 700 taking 3 decimal places
We open the created text document and paste the variables **Voltage, Current, Freq, FP, Pt** and **Qt**.
We wait 10 seconds
We look for the path of the text file and modify its name to **T_general**.
When the time increases by one minute, the second cycle is completed, and the new time is plus one minute. This generates a new text file. The first cycle never ends, since the variable K is never modified and is always 1.

Source: Authors.

Connection to blockchain nodes

After the internal update of the chain, validation is performed on the nodes, which are previously registered in the network, to verify the connection of the servers to the network. There, the IP address of the nodes and their corresponding work port must be indicated. The algorithm is in charge of verifying, server by server, whether the server is connected or not. If there is no communication with one of the servers, the algorithm stops and does not perform more actions until all the nodes are connected.

Likewise, in this blockchain, four nodes were simulated in the same physical device, where each one has the same IP address but a different port. Table 1 shows the addressing of the servers.

Table 1. Addressing the blockchain nodes

Server	IP Address	Local work port
1	127.0.0.1	5004
2	127.0.0.1	5005
3	127.0.0.1	5006
4	127.0.0.1	5007

Source: Authors.

Longest system chain update

Once all the network nodes are connected to the current server, the algorithm validates the longest chain for each node. This process is carried out by asking each linked server its chain and its length. If any of the node's chains are longer than the one in the algorithm, the network's longest chain replaces it. If the chain in the algorithm-system is the longest, the next node is asked for a longer chain until the list of connected servers is completed.

In addition, this method allows knowing if the algorithm has the longest chain; if the algorithm does not have the longest chain, it is necessary to update the algorithm-data internally by changing the current chain by the longest blockchain chain.

When the verification is done, the algorithm prints a message indicating if it has the longest chain or if the chain has been replaced. One of the following three cases may take place.

- *Case 1 - New chain:* No chain has been created by neither the other nodes nor the algorithm, so a genesis block is established.
- *Case 2 - Existing internal chain:* This case starts from the previously developed chain. The genesis block is the first chain link; the other links correspond to the data mining of the relay either by the nodes created by the algorithm or by the other system nodes.
- *Case 3 – Existing external chain:* This case starts from the previous chain developed by another node. The genesis block is the first chain link; the other links correspond to the data mining of the relay either by the algorithm-nodes or by the other system nodes.

In either case, the algorithm prints the value of the current chain with its links and total length.

Capturing relay data

Once the chain update is finished, the algorithm connects to the relay, defining that the relay will have an IP address and a working port, as shown in Table 2. If the device is not connected, the algorithm will not continue its process.

Table 2. Relay addressing

Device	IP Address	Local work port
Relay 1	127.0.0.1	5010

Source: Authors.

Once connected, the values from the file are taken, which are delivered by the relay, and verified with the data obtained from the previous transaction of the chain, where one of the following cases will occur:

- *Case 1 - First data in the chain:* It is possible that the blockchain cable still has no information, so the first link created is the genesis block, which contains the number of the section in which is the timestamp of its creation (section is 1 as it is the first link). PROF represents the consensus by which the blockchain transaction was validated and included. The PREVIOUS_HASH defines the key of the previous link (which, in the case of the genesis block, is 0 since it does not have any previous transaction). Finally, the value of the transaction is represented as a "Genesis Block". After validating the information from the previous transaction, the algorithm-system adds the first blockchain link. This link contains relay data. Then, the algorithm continues with the data mining and validation of the chain.

- *Case 2 - Adding new data to an existing chain:* It is probable that the chain has more than two created sections (genesis and another block), so, the previous block is validated through the relay time data. Then, the data is compared with the relay time data to be added to the chain; if the information is not repeated when compared, the new relay record is added to a new link.

- *Case 3 - Captured data = Data from the previous block:* Based on Case 2 of this section, where there is a chain with two or more blocks created, the relay time data from the previous segment is considered and compared with the current capture time, but the algorithm observes that the new data is the same as the previous one. If this is true, the algorithm cannot add the 'new data', since the server would be adding repeated values in the time delivered by the relay to the blockchain.

This comparison guarantees that any server that wants to add a new piece of data to the blockchain compares whether it is repeated data or not. If the data is repeated, it will not be added, and the network chain will be updated.

RESULTS

The results obtained for each of the stages of the previously described methodology are shown below.

Section transaction and mining

Once validated, by relaying non-repetition data to add, the algorithm proceeds with the new transaction and the mining of the new block. Figure 3 created blockchain transactions and show how a new transaction is added to one section. In this case, Figure 3 displays the second one ("1_index":2), where the added equipment ("A. Equipment") is observed, which node adds that new transaction ("B. Server"), and what information the server brings from the relay ("C. Information").


```
{
    "1_length": 5,
    "2_chain": [
        {
            "1_Index": 1,
            "2_Estampa_de_tiempo": "2021-09-28 06:58:11.088496",
            "3_proof": 1,
            "4_previous_hash": "0",
            "5_transactions": [
                "Bloque Génesis"
            ]
        },
        {
            "1_Index": 2,
            "2_Estampa_de_tiempo": "2021-09-28 06:59:30.842493",
            "3_proof": 533,
            "4_previous_hash": "81c5919c6a13b571179148a20f58a82e82f3b3a5a8fa2d75236d67907cc0075b",
            "5_transactions": [
                {
"A.
      Equipo": "Rele_1",
"B.
      Servidor": "Red_BKC_NODO_5005",
"C.
      Informacion": "28 09 2021 06 58\nRelay 1\nBogotá Electrical Substation - U.D.\n\n\nOpenings caused by faults: 15.0\n\n\nTime Stamp;28 09 20
                }
            ]
        },
        {
            "1_Index": 3,
            "2_Estampa_de_tiempo": "2021-09-28 07:05:50.497756",
            "3_proof": 45293,
            "4_previous_hash": "3aa16b100b31ccd8b287b2cbaa52fb3c6a4426fd24bc22c30fa53a78c755c8e0",
            "5_transactions": [
                {
"A.
      Equipo": "Rele_1",
"B.
      Servidor": "Red_BKC_NODO_5005",
"C.
      Informacion": "28 09 2021 07 04\nRelay 1\nBogotá Electrical Substation - U.D.\n\n\nOpenings caused by faults: 19.0\n\n\nTime Stamp;28 09 20
                }
            ]
        },
        {
            "1_Index": 4,
            "2_Estampa_de_tiempo": "2021-09-28 07:06:37.856713",
            "3_proof": 21391,
```


Figure 3. Created blockchain transactions

Source: Authors.

When adding the transaction, the block employs the previous block key or “Previous_hash” and the consensus protocol or PROF. Then, the algorithm performs the proof of work or “Proof_of_of_work.” This proof confirms the transaction and produces a new block in the chain through the SHA256 encryption and validation algorithm, an algorithm that uses the "Previous_hash"to encrypt the recent key of the block to be added.

Publication of the chain on the blockchain

When completing the block validation and mining, the internal chain of the node is updated with the new block and reconnected to the other nodes, thus leaving a precedent that there is a recent blockchain publication.

Multiple connections between network nodes

According to Figure 4, nodes can connect between each other in the local network. Likewise, nodes update the information that each one has according to the longest chain available in the network.

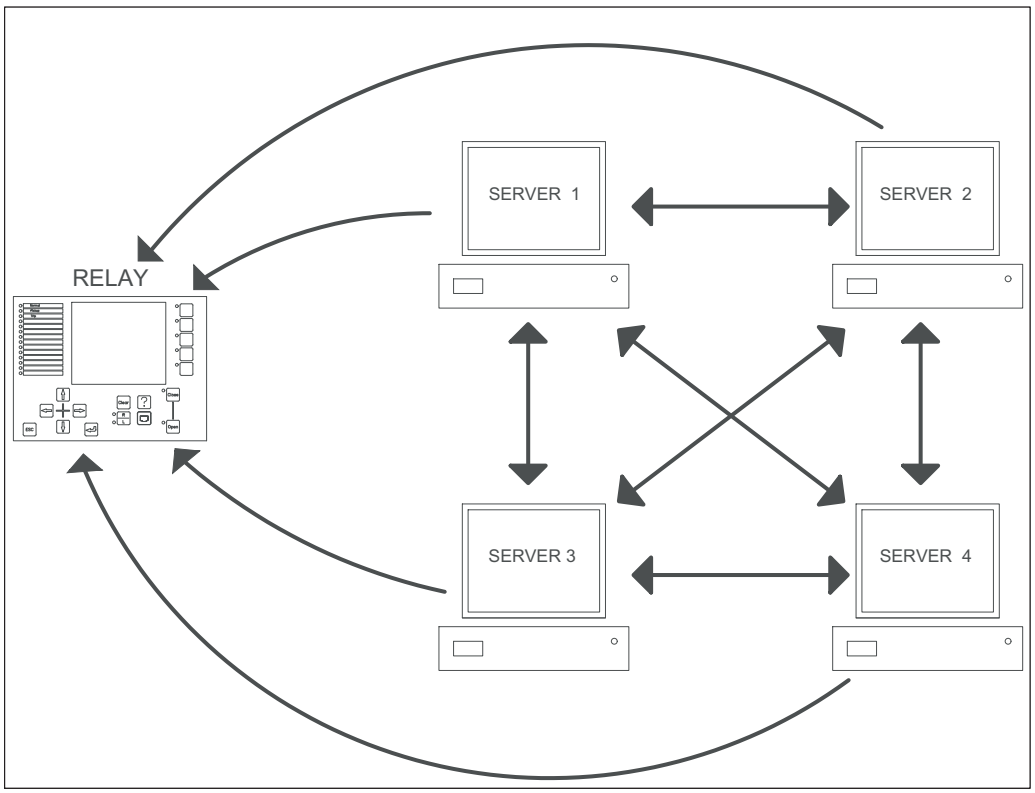

Figure 4. Connecting equipment on the blockchain

Source: Authors.

Information decentralization

The relay-obtained data is similar to the one obtained from a substation or even a better power system. These results prove that not only does one server have the information in a centralized way, as commonly handled, but each server in the network may handle the same data and update according to the executed tests.

Greater control of information

Everyone can interrogate the relay and define whether the information delivered is already in the chain or constitutes new data. Likewise, this algorithm prevents the addition of altered information from the devices to be monitored.

Performance of the device used as a server

When executing the steps described in the methodology and the longer the chain is, the equipment used to run the algorithm presents delays in its update; the algorithm's processor increases the temperature and turns on the cooling fans.

Execution times for network update

The update of each server with the blockchain chain is delayed by about 10 seconds, considering that the only processes running on the machine are the algorithm and Postman (the graphical interface that allows visualizing the network values and communicating with the algorithm).

Conclusion

This work developed a blockchain algorithm capable of connecting multiple nodes to the network and decentralizing the information. In this algorithm, additional equipment such as a relay can be contacted. Likewise, the servers connected to the network interrogate the device, collecting information on measurements and events that have occurred during the last minute, thus achieving the capture of such information and adding it to the chain without repetition.

In addition, it is relevant to highlight the decentralization of the information compared to conventional event recording methods. This allows greater control of the information and much faster and more reliable access by network users to the stored data. Moreover, to develop a blockchain with a high amount of equipment, it is recommended to use machines with high processing capabilities, higher RAMs, and modules that intervene in the information linking process to the equipment with the greater capacity, both in storage and performance. These characteristics allow the algorithm to run smoothly and in the shortest possible time.

In short, using this type of technology in an environment where information must be transported from the substation to a control center and give orders to the equipment is not recommended, since the execution times of the commands can delay the proper operation of the algorithm. However, it is advisable to manage the algorithm as an extensive decentralized database with few cybersecurity vulnerabilities.

FUTURE WORK

Over time, more data could be integrated, which would depend on the protocols handled by the substation. For instance, IEC61850 could carry data on measurements, positions, and other electrical and mechanical cell variables on time by dealing with more precise standards for information handling.

In the same way, the possible creation of a graphical interface allows a better user experience when reading data and performing validation.

Finally, the expansion of this algorithm into a higher network could be conducted as future research, with the integration of a minimum of 15 remotely connected computers through the Internet, thus allowing participation at an international level.

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INVESTIGACIÓN

Branch Optimal Power Flow Model for DC Networks with Radial Structure: A Conic Relaxation

Flujo de potencia óptimo de ramas para redes DC con estructura radial: una relajación cónica

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Abstract

Objective: This work involves a convex-based mathematical reformulation of the optimal power flow problem in DC networks. The objective of the proposed optimization model corresponds to the minimization of the power losses throughout all the network branches considering a convex conic model that ensures finding the global optimum solution.

Methodology: This work is split into three stages. The first stage presents the mathematical model of optimal power flow for DC networks and all the geometric features that make it non-convex. The second stage presents the convex reformulation from a second-order conic relaxation. The third stage shows the main characteristics of the DC system under study, as well as the optimal solution of the power flow problem and its comparisons with some methods reported in the specialized literature.

Results: The numerical validations demonstrate that the proposed convex optimal power flow model obtains the same solution as the exact model of the problem with an efficiency of 100 %, which is in contrast with the variability of the results that are presented by the metaheuristic techniques reported as comparison methodologies.

Conclusions: The proposed second-order conic relaxation ensured the convexity of the solution space and, therefore, the finding of the optimal solution at each execution, in addition to demonstrating that, for optimal power flow problems in DC networks, the numerical performance is better than most of the comparative metaheuristic methods and that the solution provided by the proposed relaxation is equivalent to that provided by the exact model.

Keywords: direct current networks, second-order conic relaxation, non-linear programming model, convex optimization

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Resumen

Objetivo: Este trabajo plantea una reformulación matemática de naturaleza convexa del problema de flujo de potencia óptimo en redes de corriente continua (DC). El objetivo del modelo de optimización propuesto corresponde a la minimización de las pérdidas de potencia en todas las ramas de la red considerando un modelo cónico convexo que garantice el hallazgo de la solución óptima global.
Metodología: Este trabajo está dividido en tres etapas: la primera presenta el modelo matemático de flujo de potencia óptimo para redes DC y todas las características geométricas que lo hacen no convexo; la segunda presenta la reformulación convexa a partir de una relajación cónica de segundo orden; la tercera etapa presenta las principales características del sistema DC bajo estudio, además de la solución óptima del problema de flujo de potencia y sus comparaciones con algunos métodos reportados en la literatura especializada.
Resultados: Las validaciones numéricas demuestran que el modelo de flujo de potencia óptimo convexo propuesto encuentra la misma solución el modelo exacto del problema y tiene una eficiencia del 100 %, lo cual contrasta con la variabilidad de resultados que presentan las técnicas metaheurísticas reportadas como métodos de comparación.
Conclusiones: La relajación cónica de segundo orden propuesta garantizó la convexidad del espacio de soluciones, y, por tanto, el hallazgo de la solución óptima en cada ejecución. Además, demostró que, para problemas de flujo de potencia óptimo en redes DC, tiene el mejor desempeño numérico que la mayoría de los métodos metaheurísticos comparativos; y que la solución provista por la relajación propuesta es equivalente a la proveída por el modelo exacto.
Palabras clave: redes de corriente continua, relajación cónica de segundo orden, modelo de programación no lineal, optimización convexa

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INTRODUCTION

For decades, distribution networks have been traditionally designed under the alternating current (AC) paradigm (Starke *et al.*, 2008, Gelani *et al.*, 2019, Garcés *et al.*, 2014). However, in recent

years, the accelerated advance in power electronics, renewable generation, and energy storage systems has steered these distribution networks towards the direct current (DC) paradigm (Montoya *et al.,* 2020a, Serra *et al.,* 2021). This shift is mainly supported by the following advantages: (i) multiple generation and energy storage technologies work directly with DC technologies (photovoltaic sources, batteries, supercapacitors, and superconducting coils), which implies that the number of power electronic interfaces can be reduced when these are connected to DC networks instead of AC networks (Lotfi & Khodaei, 2017, Hidalgo-Mora *et al.,* 2014); (ii) DC distribution feeders are more efficient in terms of voltage profiles and power losses since reactive power and frequency are non-existing concepts within these grids (Garcés, 2018, Gil-González *et al.,* 2020, Grisales-Noreña *et al.,* 2020); and (iii) DC networks are easily controllable since the main goal is to control the voltage profile in all the buses of the grid without the need for frequency synchronization (Parhizi *et al.,* 2015).

To analyze DC distribution networks, the literature has proposed multiple approaches regarding power flow and optimal power flow analysis. Some of them are nonlinear analysis of DC grids with constant power loads (Simpson-Porco *et al.,* 2015) and convergence analysis of the Newton-Raphson and Gauss-Seidel methods (Garcés, 2017,Garcés, 2018). The most common approaches in the field are based on second-order, semidefinite programming and interior point methods under nodal representation of the DC network (Bahrami *et al.,* 2017, Li *et al.,* 2018, Montoya & Gil-González, 2021) and metaheuristic approaches based on particle swarm and genetic algorithm methods (Grisales-Noreña *et al.,* 2019). It is worth mentioning that, in the case of optimal power flow analysis, not all methods guarantee optimum global finding, as is the case of nonlinear programming models and metaheuristics (except semidefinite and second-order cone programming). Therefore, alternative methods are required (convex optimization approaches) which find the optimum global by transforming the non-convex solution space of the original model into a convex equivalent model via conic representation. For this reason, in this research, we proposed an alternative branch optimal power flow formulation for DC networks that has previously proposed for AC networks in (Farivar & Low, 2012), with the advantage that, for a DC grid with n nodes and l lines, the number of required variables is $2(n+l)$, whereas existing convex methods require (n^2+n) variables (Li *et al.,* 2018). This contribution may significantly reduce the efforts in terms of the processing time.

The remainder of this document is organized as follows: the *Branch power flow formulation* section presents the exact formulation of the branch optimal power flow model for DC distribution networks; *Conic relaxation* describes the second-order cone programming model with the relaxed branch optimal power flow; *Computational validation* presents the test system characteristics and the computational validation of the proposed convex model regarding metaheuristics and exact methods; and, finally, *Conclusions* presents the main concluding remarks of this research, as well as guidelines for future work.

BRANCH POWER FLOW FORMULATION

The power flow problem and its optimization variants (i.e., optimal power flow models) are classically formulated via nodal representation (Garcés, 2017). In these formulations, it is intended not to use current and branch power variables, which implies that these must be calculated once all the voltage variables are known. However, the power flow problem can be reformulated using branch and nodal variables at the same time by means of the branch-based power flow formulation (Farivar & Low, 2012). Consider the second Tellegen theorem applied to each node of the network except the slack node, which provides the following set of expressions:

$$p_{jk} - R_{jk} i_{jk}^2 - \sum_{m:(k,m) \in E} p_{km} = p_k, \ \forall (j,k) \ \in \ E \tag{1}$$

where $p_{jk}(p_{km})$is the power flow through the line that connects nodes j and k (k and m, respectively), i is the current flowing through the line that connects nodes j and k, p is the power injection at node k defined as demand minus generation, and R_{jk} represents the resistive effect in line $j-k$. Note that E is the set that contains all the branches of the network. Ohm's law applied at each branch results in

$$i_{jk} = \frac{v_j - v_k}{R_{jk}}, \ \forall (j,k) \ \in \ K \tag{2}$$

with v_j and v_k being the voltage values at nodes j and k, respectively.

The power in the DC networks for each branch is defined as

$$p_{jk} = v_j i_{jk}, \ \forall (j,k) \ \in \ E \tag{3}$$

To formulate the optimal power flow model, the scientific literature widely uses the minimization of power losses in all branches, which generates the following nonlinear programming optimization model:

Objective function:

$$\min p_{loss} = \sum_{(j,k) \in E} R_{jk} i_{jk}^2 \tag{4a}$$

Set of constraints:

$$p_{jk} - R_{jk} i_{jk}^2 - \sum_{m:(k,m) \in E} p_{km} = p_k, \ \forall (j,k) \ \in \ E \tag{4b}$$

$$i_{jk} = \frac{v_j - v_k}{R_{jk}}, \ \forall (j,k) \ \in \ E \tag{4c}$$

$$p_{jk} = v_j i_{jk}, \forall (j,k) \ \in \ E \tag{4d}$$

Remark 1. *The optimization model defined in (4) is known in the literate as the optimal branch power flow model (Farivar & Low, 2012), which is nonlinear and non-convex due to the square of the currents in (4b) and the product between voltages and currents in (4d).*

Note that an equivalent optimization model can be obtained from (4) by making some algebraic manipulations. To this effect, let us pre-multiply (4c) by v_j, which produces

$$v_f^2 - v_j v_k = R_{jk} v_j i_{jk},\ \forall (j,k)\ \in\ E \tag{5a}$$

$$v_f^2 - R_{jk} p_{jk} = v_j v_k,\ \forall (j,k)\ \in\ E \tag{5b}$$

Now, if we raise (4c) to the square in both sides, we have:

$$R_{jk}^2 i_{jk}^2 = (v_j - v_k)^2,\ \forall (j,k)\ \in\ E \tag{6a}$$

$$R_{jk}^2 i_{jk}^2 = v_j^2 - 2 v_j v_k v_k^2,\ \forall (j,k)\ \in\ E \tag{6b}$$

Note that, if Equation (6b) is substituted into Equation (5b) and some algebraic manipulations are made, it yields

$$v_k^2 = v_j^2 - 2 R_{jk} p_{jk} + R_{jk}^2 i_{jk}^2,\ \forall\ \in\ E \tag{7}$$

To obtain an equivalent model, let us define two auxiliary variables, $l_{jk} = i_{jk}^2$ and $u_j = v_f^2$.

With these new variables, the optimal branch power flow model (4) can be rewritten as follows:

Objective function:

$$\min\ p_{loss} = \sum_{(j,k)\ \in\ E} R_{jk} l_{jk} \tag{8a}$$

Set of constraints:

$$p_{jk} - R_{jk} l_{jk} - \sum_{m:(k,m)\ \in\ E} p_{km} = p_k,\ \forall (j,k)\ \in\ E \tag{8b}$$

$$u_k = u_j - 2 R_{jk} p_{jk} + R_{jk}^2 l_{jk},\ \forall (j,k)\ \in\ E \tag{8c}$$

$$p_{jk}^2 0 = u_j l_{jk},\ \forall (j,k)\ \in\ E \tag{8d}$$

Remark 2. *The optimal branch power flow model defined in (8) is still non-convex due to the presence of the product between auxiliary variables u_j and l_{jk} in equality constraint (8d). However, this complication can be dealt by using a conic relaxation through its hyperbolic representation, as presented in the next section.*

CONIC RELAXATION

Conic optimization is a subfield of convex optimization that allows relaxing some class of optimization problems using second-order cone constraints (Farivar & Low, 2012), which is especially attractive when faced with products among continuous variables. Even if the cones are nonlinear inequality constraints, they are convex since these constraints are in the interior space of the cone (Benson & Saglam, 2013). Then, the conic relaxation of the branch optimal power flow model consists of rewriting (8) with its hyperbolic equivalent (Farivar & Low, 2012). To do so, let us consider the following relation:

$$u_j l_{jk} = \frac{1}{4}(u_f + l_{jk})^2 - \frac{1}{4}(u_j - l_{jk})^2,\ \forall (j,k)\ \in\ E \tag{9}$$

Now, if we substitute (9) into (8d), then, we have

$$(2p_{jk})^2 = (u_j + l_{jk})^2 - (u_j - l_{jk})^2,\ \forall (j,k)\ \in\ E \tag{10a}$$

$$(2p_{jk})^2 + (u_j - l_{jk})^2 = (u_j + l_{jk})^2,\ \forall (j,k)\ \in\ E \tag{10b}$$

Observe that (10) can be rewritten using the Euclidean norm as follows:

$$\left\| \begin{matrix} 2p_{jk} \\ u_j - l_{jk} \end{matrix} \right\| = u_j + l_{jk},\ \forall (j,k)\ \in\ E \tag{11}$$

Remark 3. *The structure of Equation (11) is still non-convex due to the equality sign. However, as suggested by Farivar & Low, 2012, this can be relaxed with a lower-equal symbol, which allows (11) to become a second order conic constraint.*

With the conic relaxation of (12), the branch optimal power flow model defined in (8) takes the convex structure of (13).

Objective function:

$$\min p_{loss} = \sum_{(j,k)\ \in\ E} R_{jk} l_{jk} \tag{13a}$$

Set of constraints:

$$p_{jk} - R_{jk} l_{jk} - \sum_{m:(k,m)\ \in\ E} p_{km} = p_k,\ \forall\ \in\ E \tag{13b}$$

$$u_k = u_j - 2R_{jk} p_{jk} + r_{jk}^2 l_{jk},\ \forall (j,k)\ \in\ E \tag{13c}$$

$$\left\| \begin{matrix} 2p_{jk} \\ u_j - l_{jk} \end{matrix} \right\| = u_j + l_{jk},\ \forall (j,k)\ \in\ E \tag{13d}$$

Remark 4. *The most important characteristic of the second-order cone programming branch optimal power flow model defined in (13) is that it guarantees finding the global optimum with interior point methods under well-defined voltage and demand conditions (Li et al., 2018). In addition, this convex relaxation creates a lower number of variables than the classical convex models reported in the literature, such as semidefinite programming (Bahrami et al., 2017) and SOCP models that only work with voltage variables (Li et al., 2018).*

It is worth mentioning that this research does not present the methodology for a solution, since the main contribution of this research is indeed the convexification of the exact nonlinear programming model (8) using second-order cone programming as presented in (13). This implies that, due to the convexity of the solution space and of the objective function with any convex optimizer (e.g., CVX for MATLAB or CVXPY for Python), it is possible to reach the global optimum of the studied problem with a 100 % of repeatability properties.

Computational validation

To demonstrate the effectiveness and robustness of the proposed SOCP model presented in (13), we considered a large-scale medium-voltage distribution network composed of 69 nodes and 68 lines (radial configuration) with the configuration depicted in Figure **1**.

The 69-node test feeder operates at 12.660 kV. All the numerical information of this test feeder can be consulted in the work by Montoya *et al.*, 2019a. For this test feeder, we considered the likely dispatch of three distributed generators located at nodes 21, 61, and 64, with maximum generation capabilities of 12 pu each (Montoya & Gil-González, 2021). In addition, to compare the performance of

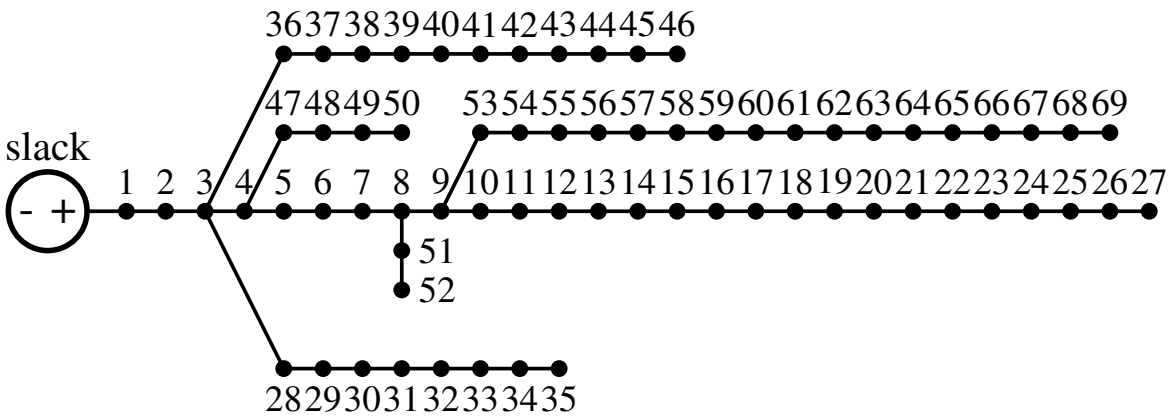

Figure 1. Schematic connection among nodes for the 69-node test feeder

Source: (Montoya *et al.*, 2019a).

the proposed SOCP optimization model, we considered different metaheuristic approaches, typically reported in the literature for optimal power flow analysis in DC networks, namely black-hole optimization (BHO) (Velásquez *et al.*, 2019), elephant swarm water search algorithms (ESWSA) (Montoya *et al.*, 2019b), continuous genetic algorithms (GGA) (Montoya & Gil-González, 2021), sine-cosine algorithms (Giraldo *et al.*, 2019), vortex search algorithms (Montoya *et al.*, 2020b), and an exact approach based on interior points available in the GAMS software (Montoya & Gil-González, 2021).

Table **I** shows the numerical performance of all the comparative methodologies for optimal power flow analysis in DC grids. It is worth mentioning that all the metaheuristic methods were evaluated 100 times to determine the best possible solution reached by each one of them.

The numerical results in Table **I** reveal that:

- The best metaheuristic approach for dealing with optimal power problems in DC distribution networks is to the VSA approach. Its variations regarding the optimal solution are in the order of milliwatts, which constitutes an exact methodology from the numerical point of view.
- The worst behavior regarding metaheuristics for optimal power flow solution is the result reported by the BHO. This is due to the fact that it is a simplification of the classical particle swarm optimizer, which is easily stuck in local optimal solutions (Gupta *et al.*, 2016).
- The proposed SOCP model for optimal power flow analysis in DC distribution networks allows reaching the global optimum solution for this problem since its solution matches with the interior point method available in GAMS. This is to be expected, as the solution of the SOCP models has been elaborated with interior point methods in the scientific literature (Benson & Saglam, 2013).

Table I. Numerical results in the OPF problem with different comparative approaches

Method	Generation (kW)	Power losses (kW)
BHO	[460,21, 1170,28, 639,88]	5,025771
ESWSA	[495,80, 1049,55, 699,62]	5,005033
CGA	[401,31, 1191,55, 584,05]	4,982861
SCA	[499,86, 1199,90, 564,26]	4,557555
VSA	[455,47, 1200,00, 584,85]	4,454562
GAMS	[453,21, 1200,00, 585,16]	4,454342
SOCP	[453,22, 1200,00, 585,17]	4,454342

Source: Authors.

Figure 2 presents the percentage of power losses minimization, considering that the base case without distributed generation has an initial power loss of about 153,847557 kW.

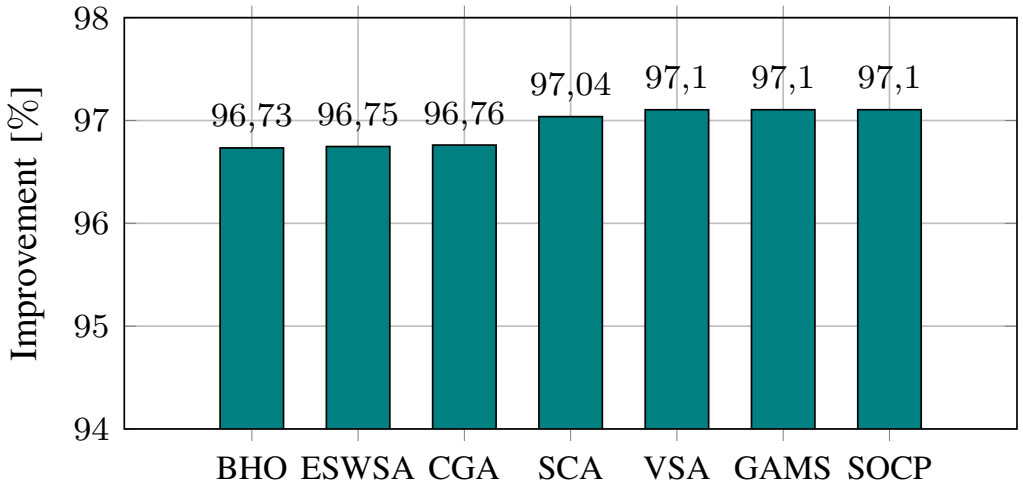

Figure 2. Improvement of the power losses reached by the proposed SOCP reformulation and the comparative methods

Source: (Montoya *et al.*, 2019a).

Note that the results in Figure 1 confirm that VSA, GAMS, and the proposed SOCP approach are the best methodologies regarding power losses minimization via optimal power flow analysis with distributed generation. Also, the most important implication of these results is that, in the case of DC networks, the total power losses can be minimized by up to 90 %, which is not the case, with most of the results reported for the 69-nodes test feeder with distributed generation around 60 % (Kaur *et al.*, 2014). This difference between both technologies can be attributed the reactive effects inherent to AC networks, which do not arise in the case of DC distribution.

Conclusion

A second-order cone programming model for optimal power flow analysis in DC distribution networks that combines nodal and branch variables has been presented in this paper. The exact non-linear programming model was convexified via the relaxation of the power sent from node j to node k, *i.e.*, $p_{jk} = v_i i_{jk}$, with its conic equivalent of hyperbolic representation. The numerical results in the 69-node test feeder demonstrate that the proposed SOCP model allows reaching the global optimal solution for the optimal power flow problem in DC distribution networks with distributed generators, given that its results are better than metaheuristic methods such as BHO, ESWSA, CGA, and

SCA. In addition, numerically speaking, the only metaheuristic method that can reach a near-optimal solution is the VSA approach, which was compared with the proposed SOPC model and the interior point methods available in the GAMS software.

Future work

As future work, it will be possible to embed the proposed SOCP model for the optimal power flow method in a master-slave optimization algorithm guided by a discrete metaheuristic method (master) to determine the optimal location and sizing of the distributed generators in DC distribution networks, where the SOCP (slave) proposed model is entrusted with determining the optimal sizes of these distributed generators for each possible location provided by the master algorithm.

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INVESTIGACIÓN

Using Environmental Education and Healthy Housing as Strategies for Household-Level Prevention of COVID-19

Educación ambiental y vivienda saludable como estrategias de prevención del COVID-19 a nivel domiciliario

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Abstract

Context: The COVID-19 is the most recent global health concern that affects human health mainly the respiratory system with more than 170 million people affected by the virus worldwide. Also, Latin America has been emerging as an epicenter of contagion, and transmission is gradually increasing among the communities in each of the countries analyzed. The infection of more than 30 million people in Latin America supposes the construction of new models and habits of public health that promote attitudes to reduce the number of cases and mortality.

Method: A proposal was defined based on three frameworks and models—the principle of healthy housing promoted by the Panamerican Health Organization, the four types of knowledge transfer without memorization proposed by the OECD, and the theory of social constructivism (in which knowledge is built from a present reality). This proposal is aims to help a community to understand the health risks present at home so that they can prevent the spread of the virus COVID-19 through the use of good practices.

Results: The proposal shows categorized risk factors at home that increase the possibility of contagion of COVID- 19 and getting infected; also, it presents possible solutions to these factores, which focus on good practices of healthy housing to improve habitability and prevent diseases that also allow the virus to spread.

Conclusions: It is necessary to implement strategies that humanize public health problems and that in turn include the

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knowledge that the field of engineering can contribute to solve these problems. In addition, these strategies must emerge from practical work focused on the community. An example of this is the proposal for good practices for healthy housing to prevent the spread of the COVID-19 virus.

Keywords: Water quality, constructivism, knowledge transfer, COVID-19.

Resumen

Contexto: El COVID-19 es el problema de salud global más reciente que afecta la salud humana principalmente el sistema respiratorio con más de 170 millones de personas afectadas por el virus en todo el mundo. Asimismo, América Latina se ha venido perfilando como un epicentro de contagio, y la transmisión va aumentando paulatinamente entre las comunidades de cada uno de los países analizados. La infección de más de 30 millones de personas en América Latina supone la construcción de nuevos modelos y hábitos de salud pública que promuevan actitudes para reducir el número de casos y la mortalidad.
Método: Se definió una propuesta basada en tres marcos y modelos: el principio de vivienda saludable promovido por la Organización Panamericana de la Salud, los cuatro tipos de transferencia de conocimiento sin memorización propuestos por la OCDE y la teoría del constructivismo social (en la que se construye el conocimiento) de una realidad presente). Esta propuesta tiene como objetivo ayudar a una comunidad a comprender los riesgos para la salud presentes en el hogar para que puedan prevenir la propagación del virus COVID-19 mediante el uso de buenas prácticas.
Resultados: La propuesta expone factores de riesgo categorizados en el hogar que aumentan la posibilidad de contagio y de contagiarse de COVID-19; además, presenta posibles soluciones a estos factores, las cuales se enfocan en buenas prácticas de vivienda saludable para mejorar la habitabilidad y prevenir enfermedades que también permiten la propagación del virus.
Conclusiones: Es necesario implementar estrategias que humanicen los problemas de salud pública y que a su vez, incluyan los conocimientos que el campo de la ingeniería puede aportar para solucionar estos problemas. Además, estas estrategias deben surgir de un trabajo práctico centrado en la comunidad. Un ejemplo de ello es la propuesta de buenas prácticas de vivienda saludable para evitar la propagación del virus COVID-19.

Palabras clave: Calidad del agua, constructivismo, transferencia de conocimiento, COVID-19.

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INTRODUCTION

Coronavirus is now a large family of viruses that cause respiratory infections that result in diseases from simple colds to more serious illnesses such as the Middle East Respiratory Syndrome (MERS) or the Severe Acute Respiratory Syndrome (SARS) (WHO, 2004).

In December 31, 2019 the government of the People's Republic of China alerted the World Health Organization about the existence of the outbreak of a new strain of coronavirus, possibly causing a serious disease in humans, which would be referred to as SARS -CoV-2. The International Committee on Taxonomy of Viruses (ICTV) identified the new coronavirus SARS-CoV2 (COVID-19) in the Chinese city of Wuhan (Hubei Province) as the cause of acute respiratory syndromes in humans (Gorbalenya *et al.*, 2020, Lam *et al.*, 2020).

During the next two months, tens of hundreds of COVID-19 cases were detected in southern China with pneumonia symptoms of unknown etiology (De Felice *et al.*, 2020) and considered as an atypical disease under the following criteria: fever ($\geq$ 38 °C); radiographic evidence of pneumonia; low or normal white blood cell count, or low lymphocyte count; central system involvement; and no symptomatic improvement after antimicrobial treatment for 3 to 5 days following standard clinical guidelines.

In this sense, coronaviruses are important pathogens that can affect humans and animals, infecting the respiratory, gastrointestinal, liver, and central systems (Chen *et al.*, 2020). Despite being detected relatively quickly, the virus has shown a facility to spread, thus generating a significant increase of COVID-19 cases throughout the planet in a short period of time.

Currently, the World Health Organization reports 170.051.718 confirmed cases of COVID-19 and 3.540.437 deaths worldwide (as of May 31, 2021). Graph 1 shows the comparison between regions most affected by the virus globally. This graph shows significantly growing infections presented in Americas (67,178,933 infected).

The behavior among countries in Latin America has revealed them as an endemic region, one of the epicenters of the virus worldwide. On the one hand, Brazil has a high number of registered cases, close to seventeen million patients (16.391.930 total cases), and countries such as Argentina and Colombia (3.702.422 cases and 3.342.567 cases, respectively) show a trend indicating exponential increases (Yang *et al.*, 2020).

The guidelines for the spread of epidemics through the World Health Organization indicate that COVID-19 spreads through droplets from the mouth or nose (product of the patient's symptoms) (Yang *et al.*, 2020).

The infection of the person comes from the inhalation of these droplets that contain the virus. The epidemiological care guidelines require certain care and consideration of the contagion as serious: hand washing and use of anti-bacterial components for continuous use, social distancing, and in case of symptoms, quarantine for a total of 15 days.

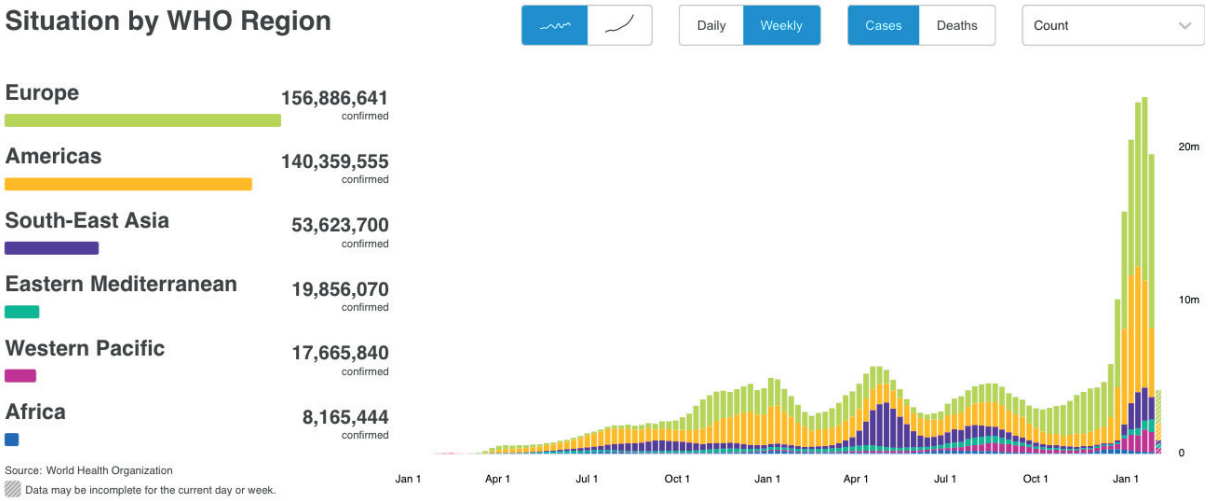

Figure 1. COVID-19 cases by regions. World Health Organization, 2021

Source: https://covid19.who.int/

Given the limited knowledge of the disease, the WHO indicates as characteristic symptoms in people infected by COVID-19 dry cough, fatigue, and high fever. On some occasions, some cases have reported nasal congestion, muscle aches, sore throat, conjunctivitis, diarrhea, and alterations in the senses of taste and smell (Chen *et al.*, 2020, Huang *et al.*, 2020).

The governments throughout the world have implemented different policies and actions such as isolation and social distancing to reduce the number of infected cases in their respective countries. Particularly in Latin America, the need to decrease the number of infected and deceased has been a prevailing requirement given the alarming spread of the virus.

Isolation refers to the separation of people who are ill with COVID-19 symptoms and who may be contagious, thus preventing the spread of the disease. The quarantine restricts individual activities and isolates those asymptomatic people who have been exposed to the virus. The main objective is to prevent the spread of the disease, from the moment the exposure happens, after the patient presents any symptoms, and until those symptoms disappear or reduce their intensity. Physical distance of approximately 1.5 meters between individuals is also recommended.

In short, the spread of the disease and the significant advance of the COVID-19 virus has required a series of actions from the different public and private entities that support mitigating the transmission of the virus and reducing the economic impact that has emanated from this problem.

The research group called Management and Technology for the Sustainability of Communities (Faculty of Engineering of the Catholic University of Colombia), the Institute of Technology, Infrastructure, and Territory (Federal University of Latin-American Integration), and the Civil Engineering program of the University of Salerno (Italy) have created a synergy of work under the juxtaposition of objectives with universal social responsibility. This COVID-19 pandemic has produced a need to

promote initiatives to transfer knowledge from different disciplines in various academic and research institutions, that is, information that help to reduce the risk of contagion at home.

The study presented is based on the principle of healthy housing based off a strong social component and community work. This study relates concepts of public health and quality of life in informal communities with a high-risk profile of contagion by COVID-19. Exposure continues in spaces with reduced hygiene (in some cases unhealthy) at home; and poor hygiene and health practices encourage the transmission of this highly contagious virus. Therefore, a study of the variables that help to spread the virus at home was necessary to try and prevent the spread of COVID-19, considering the possibility of contagion in the context of informal homes and inadequate housing designing (which is is common in informal homes).

Determining the strategies and new models that intervene positively in informal communities is a technical and academic component for regions with high degrees of vulnerability, and it was also crucial for the development of this study. Thus, adoption of techniques and methodologies throughout the life cycle of the project was part of the process to guarantee sustainability standards that would improve the life of communities that are exposed to COVID-19 infections.

Consequently, this public health emergency in Latin America may also be seen as an opportunity to build better health strategies within different communities and to reduce the problems that trigger health-disease processes.

Understanding the current configuration of a vulnerable community facilitates the creation of new perspectives that may help to rearrange such communities from a social, dynamic, and historical point of view. Addressing norms, values, attitudes, and cultural patterns is fundamental in the analysis of vulnerability to contagion of COVID-19.

Furthermore, the socialization of a project like this, oriented to communities is an essential part of the expansion of new perspectives in the context of urban or social habitat development because communities tend to adopt and endorse technical interventions like this one whether they are a success or a failure.

The construction of processes and strategies allows for the development of sustainable competencies in its four axes—economic, social, environmental, and cultural, to plan new prevention mechanisms to attain good sustainable housing practices. This study represents a new participatory educational model that motivates informal communities to internalize the problems that cause processes of health-disease in the context of housing and to understand the importance of living in healthy environments.

METHODOLOGY

A relationship was found between the regulations for housing management in vulnerable communities and the incidence and increase of infections in families, and it indicates that the design of

a house should consider systemic components related to public health in terms of the spaces in the house. It also allowed to develop design guidelines in housing that may help to face the current COVID-19 problem, facilitating the teaching-learning process and the transmission of knowledge about this topic (Organización Panamericana de la Salud, 2003).

The methodology developed shows categories and risk factors in a home that make people more susceptible to the contagion of COVID-19, as well as possible solutions focused on good practices of healthy housebuilding and homemaking.

This proposal supports new ways of awareness of habitat development, both in the communities and in the academic sphere, promoting educational spaces for participatory learning. Therefore, when transferring knowledge to communities in situations of vulnerability due to direct exposure to COVID-19, it is important to transmit community learning skills and their management. In the academic environment, teamwork, managerial participation in the community, and the application of new technologies are encouraged.

To address the issue of health at home, it is necessary to bear in mind the cultural and socioeconomic aspect of the population who benefits from it; this will provide necessary elements to communicate and identify their housing reality, proposing pedagogical tools that generate critical thinking and become a bridge between theory and practice. This tool also needs to consider behavior patterns, values, social skills, and the previous knowledge of the community.

This work does not aim for the memorization of data by the people within the addressed community, but that they elaborate their own concepts through the identification and association of their current situation at home, with previously established risk factors.

The objective is to bring awareness to people about the risks associated with the transmission and contagion of COVID-19 and their relationship with unsanitary conditions and incorrect design and hygiene practices at home. This initiative seeks to generate and transmit knowledge from community work, capitalizing on the prevention of COVID-19 transmission from home as an axis of integration; therefore, it is necessary to explain how this work intended to be carried out.

(Sveiby, 1997, p.37) proposes that knowledge is "a capacity to act;" it is a dynamic and above all tacit topic that cannot be described in words. The author explains that in the everyday environment of social interaction, the idea of knowledge can be explained with the concept of competences, which contain explicit knowledge, skills, experiences, and value judgments.

The Organization for Economic Cooperation and Development OECD (1996) proposes four types of key knowledge when establishing a transfer of concepts without memorization:

Know-what: It refers to the data or specific information about any aspect. For example: How many children and older adults are at risk of COVID-19 infection in vulnerable communities in the country? What kind of good practices in healthy housing have been applied in houses to prevent contagion?

This is encoded knowledge known as "information," and it is obtained by reading books or accessing databases.

Know-why: This is the scientific knowledge of laws and principles of nature, such as knowing the effect that an infectious disease has on a host that lives in a contaminated environment.

The OECD explains that this type of knowledge generates in specialized spaces such as research centers and universities. Like know-what, it is codifiable knowledge easily accessed through books and databases.

Know- how: This is the skills to be able to do something. For example, the ability of a person to perform a specific task, such as adapting a living space with grids to promote ventilation in the home. Despite having the list of materials and instructions for its construction, not all people perform this task well because it requires a certain skill based on experience.

Know-who: refers to knowing who knows what and who knows how to do what. Its importance lies in the possibility of easily accessing experts inside or outside an organization or community if they are need.

This knowledge can be encoded and generally develops from social relationships. If one is going to make a locative improvement in a house to upgrade the lighting, and there is no one with experience to do it, there will be a need to look for someone who knows how to do it well. The same applies to the formulation of a project: there will be professionals with a lot of experience who can be entrusted with the task.

(Chaparro, 2001, p. 19) defines Knowledge Societies as "societies with the capacity to generate knowledge about their reality and their environment, and with the capacity to use this knowledge in the process of conceiving, forging, and building their future. That is, to use knowledge in the permanent process of building society, through the development, permanent transformation, and consolidation of its main social institutions.

In this way, knowledge becomes not only an instrument to explain and understand reality, but also an engine of development and a driving force for social change, which is why the educational component is so valuable in the prevention of COVID-19 since it allows a change in behavior within the individual and allows communities to generate knowledge from experience.

Finally, to accomplish the objective of this work the theory of social constructivism was used. This theory states that people construct knowledge together from the knowledge that each of them possesses, which is more than the tacit kind of know-how. Starting from their present reality, which in this case focused on the health emergency caused by COVID-19 and risks generated at home.

From this reality, the social constructivism promotes an internal organization that encourages the formation of teaching communities that ensure the development of participatory instruction; this way it is possible to identify, categorize, apply, and solve a common problem by interacting with others (Cubero Pérez, 2005).

To be clear about this working method, Table **I** relates the transfer of knowledge to communities from a daily situation that requires clear actions so that people understand how a residential space is likely to promote the transmission of COVID-19.

Table I. Knowledge transfer to COVID-19

Learning proposal Social Behaviorism	**Types of knowledge (OECD)**	**Actions / type of knowledge**
Internal organization: Finding relationships within a present reality, which may require favoring association mechanisms to understand and internalize concepts and situation is in the long-term memory.	Know-what Know-why	*Identify.* It consists of analyzing the information acquired and understanding what and why it is important for a community. *Categorize.* It refers to the management of information to establish relationships between facts, concepts, principles, and procedures.
Learning Communities: The members of a community guided by experts work actively. Members with actions of cooperation and help each other during the learning.	Know-who	*Apply.* It implies making use of the knowledge already acquired and reasoning in a participatory way, knowing who does what
Participatory instruction: The community works with the support of experts to carry out more complex tasks, and in this way, carry out activities in a participatory way where the expert provides a guide and a methodological structure throughout the process, providing the community with more and more responsibility as your competence and experience increase.	Know-how	*Solve problems:* From the analyzed information, it is possible to establish causes, consequences, effects and conclusions, and transfer knowledge to the communities

Source: Own elaboration, 2021

RESULTS AND DISCUSSION

Based on what is established in the methodology, a work proposal has been determined that contemplates the four types of knowledge proposed by the OECD and the risk factors in housing are related based off social constructivism and the actions taken by the residents of a community accompanied by good practices in healthy housing to decrease the risk of contagion of COVID-19. With this work structure, it is possible to interact within an educational space with communities that are at greater risk of getting sick with pandemic decease because of ill-fitting designs in their housing units.

Table II. Factors and good practices in the face of COVID-19 infections

Risk Factors at Home	**Suggested Actions**	**Good Practices in Healthy Housing**	**Reference Parameters to Achieve Habitability and Health Conditions**	**Preventable - Foreseeable Diseases that Intensify the Contagion of COVID-19**
Lack of access to drinking water.	Improve drinking water supply	• Improvement or installation of the storage tank. • Rush arrangement. • Change of taps. • Build sedimentation systems. • Filtration and disinfection at home. • Install savings systems.	Minimum vital water of 50 liters per person per day. Ensuring consumption and basic hygiene (WHO, 2004)	Gastrointestinal infections, intestinal parasites, typhoid fever, cholera, diarrhea, leptospirosis, skin diseases, coronary heart diseases, cancer.
Lack of sufficient and separate spaces (Overcrowding).	Promote hygiene and separation of spaces	• Good hygiene practices. • Reorganization of spaces. • Manufacture of cleaning and cleaning products with biodegradable materials. • Division of spaces in the house. • Favor privacy. • Installation of doors. • Installation of shower curtains in showers.	• Maximum 3 people per room. • Separation of spaces between kitchen, toilets and rooms. • Exclusive room for parents different from that of children, and rooms separated by gender. • Private spaces (rooms) separated from social (kitchen-dining room) - and circulations- • Width of circulations and stairs minimum of 80cm (MAVDT, 2011).	Airborne spread of viral infections, tuberculosis and meningococcal diseases, gastroenteritis, skin problems, chest infections and high levels of accidents, mental health problems, depression, domestic violence, dissatisfaction and fear of crime
Inadequate basic sanitation (sanitary units and kitchen).	Review of bathroom and kitchen facilities	• Install water savers in toilets and taps. • Manufacture of natural disinfectants. • Use of racks in dishwashers. • Installation of soap dishes and towel racks in bathrooms. • Use of non-porous materials to finish wet areas.	• Wet areas in bathrooms and kitchens veneered and their design should facilitate maintenance (MAVDT, 2011).	Schistosomiasis, soil-transmitted helminths, vector and rodent diseases, diarrhea, intestinal parasites, stomach cancer and skin diseases.
Air pollution and poor ventilation.	Promote indoor air circulation. Encourage ventilation of fuel-based kitchens.	• Installation of grids. • Manufacture of natural air fresheners. • Manufacture of cleaning products. • Cleaning with biodegradable materials. • Opening windows once a day. Do not smoke in closed spaces. • Maintenance of stove burners. • Review of the connections and / or gas cylinders.	Minimum ventilation areas for air renewal and hygrothermal comfort: • 1/15 to 1/12 of the floor area in rooms and social spaces. • 1/12 to 1/10 of the kitchen and bathroom floor area (NTC 4595). • Ensure ventilation to evacuate gases from the burning of fuels in the kitchen (MAVDT, 2011).	Acute respiratory infections (Bronchitis and Pneumonia), Perinatal effects, heart diseases, chronic lung diseases Acute and chronic diseases of the respiratory tract, depression, insecurity, neurosis.

Table II continued from previous page

Risk Factors at Home	Suggested Actions	Good Practices in Healthy Housing	Reference Parameters to Achieve Habitability and Health Conditions	Preventable - Foreseeable Diseases that Intensify the Contagion of COVID-19
Floors, ceilings, and walls with holes or cracks.	Floor, wall and ceiling maintenance	• Plug holes in walls, ceiling, doors and windows. • Finished in non-porous material on floors, walls and ceiling (carraplas or graniplas). • Cleaning with biodegradable materials. • Check the adhesive mortar on walls.	Floors • Underlayment tile waterproofing walls. • Use of adhesive mortar in vertical joints. • Use of flanges in wall ties. Covers • Waterproofing of slabs with adequate sloping and leveling. • Decking materials securely anchored. • Slopes and overlaps of material according to technical requirements. (Torres & Arias, 2019)	Increased mortality from respiratory diseases in children under 5 years of age and in those over 60 years of age, strongyloidiasis, hookworms, accidents, neurosis.
Poor food handling	Correct food storage and handling	• Smooth surfaces in the kitchen (counters, tables to prepare food). • Non-perishable food shelf storage with doors. • Respect the cold chain of perishable foods (refrigerators, cold storage in clay). • Cleaning with biodegradable materials and natural disinfectants. • Location of the clean holder and disposable towels.	• Use of space and equipment for cooking, washing and storage off the floor in the kitchen (MAVDT, 2011)	Poisoning, plague, gastrointestinal infections, diseases due to microbiological toxins, cancer.
Inadequate handling of excreta and solid and liquid waste.	Sewage and garbage disposal.	• Separation campaigns at the source. • Waste reduction, reuse and recycling strategies. • Bin location to facilitate temporary and transitional storage. • Toilets connected to the sewer network and in good condition. • Construction of septic tanks, latrines or dry toilets. • Constant hand washing.	• Adequate waste management. In plastic bags and easy-to-clean cans located in a clean and dry place. • The use of elements or designs that facilitate the presence of stagnant water avoided. • The laundry room must have the possibility of covering the water tank (MAVDT, 2011).	Gastrointestinal infections, intestinal parasites, typhoid fever, cholera, diarrhea, amoebiasis, diseases transmitted by vectors and rodents, wounds, burns.
Clutter and uncleanliness.	House cleaning and care.	• Use of personal and household hygiene kits. • Make soap with used cooking oil. • Reorganization of spaces. • Discard items that are not used. • Use of ecological cleaning products.	• Bedrooms should have furniture to store clothes that are easy to clean (MAVDT, 2011)	Respiratory diseases, skin infections, infectious diseases, diseases transmitted by lice and fleas (Typhus), diseases transmitted by vectors.

Table II continued from previous page

Risk Factors at Home	Suggested Actions	Good Practices in Healthy Housing	Reference Parameters to Achieve Habitability and Health Conditions	Preventable - Foreseeable Diseases that Intensify the Contagion of COVID-19
Lack of comfort in the home (Defects in construction), lighting, temperature, noise, humidity.	Improve lighting, humidity, noise, balance the temperature in the housing unit.	• Change of tiles in poor condition. • Installation of skylights. • Relocation of furniture and fixtures. • Organization and / or setting of light bulbs. • Handling of light surfaces (walls, ceilings). • Reinforce the edges of the windows. • Cleaning the house with vinegar solution. • Location of charcoal in the corners that present water vapor.	Illumination: • Bedrooms 50 lux. Headboard in bedrooms 200 lux. • Bathrooms 100 lux. • 100 lux room. Reading space 500 lux. • Dining room 300 lux. • Kitchen 300 lux. 500 lux working área. • 100 lux ladder. • Studio 300 lux. (Comunidad de Madrid, 2004). Humidity: • Comfortable range between 20 % and 80 % relative humidity. (Ramos *et al.*, 2017) Noise: • Rooms 35dB day and 30dB night. • Corridors and kitchen: 40dB day and 35dB night. • Common access: 50dB day and 40dB night. (Comunidad de Madrid, 2004). Temperature: • Divide into 4 the Annual Average Temperature and this adds 17.2ºC. To this value add and subtract 2.8ºC to define the comfort zone or band (Ramos *et al.*, 2017)	Diseases transmitted by vectors, by rodents, animal bites, by the presence of animal excreta, diseases caused by overcrowding, by the presence of dust and humidity, wounds, respiratory problems (bronchiolitis, pneumonia, rhinitis and asthma), heart diseases and thrombosis, depression, insecurity, neurosis, violence, crime, vandalism, alcoholism, and drug addiction.

Source: Own elaboration, 2021

The proposal seeks to transfer knowledge and build a bridge between theory and practice by identifying, categorizing, applying, and contributing to solve a problem that began recently with the spread of COVID-19, a problem that also occurs because homes do not meet design criteria that provide comfort and safety for their occupants. Table **II** presents the aspects, practices, and justification from public health of the knowledge that a community must implement in their home to improve habitability based on the concept of healthy housing and promote a theoretical-practical exercise to improve housing and its spaces, while understanding the level of risk to which its residents are exposed everyday due to the public health emergency.

Based off the table above, this study seeks to ensure that communities understand the risks to which they are exposed in their housing units and that they can acquire codified knowledge and improve tacit knowledge they already have to prevent the contagion of this global decease. The skills that communities can internalize in this participatory proposal relate to the following objectives that are set out to justify the importance of the issues presented in Table **II**:

- Identify the risk factors that are likely to increase the possibility of contagion of COVID-19 at home.
- Promote teamwork to apply the knowledge acquired in the promotion of good practices in healthy housing.
- Understand the dimension of the problem to which they are exposed by relating their home and environment to the identified risks that affect public health and represent a detriment to their quality of life.
- Strengthen relational ties in the community.
- Improve hygiene habits at home to promote healthy spaces that do not promote sources of contagion for COVID-19 or any other virus.
- Improve the skills of the populations around the application of good practices proposed in healthy housing.
- Promote initiatives and identify actors to improve the conditions of family and community life.
- Cope with the pandemic by changing poor hygiene habits and acquiring *know-how* knowledge of localized arrangements with low resources and reorganization of spaces.

Likewise, it is recommended to use situated learning as a didactic strategy to carry out this transfer of knowledge to the communities. This strategy consists of directly connecting those involved in the public health problem with its possible solution.

Therefore, it supposes the construction of knowledge from real situations, not from theories or in a decontextualized way, since the proposed iswork framed within the theme of housing and the factors of risk that arise have a direct impact on the probability of contagion of COVID-19 (Ramírez, 2012).

Furthermore, following the good practices in healthy housing that suggest limiting the exposure to the risk factors mentioned above and diseases that increase the probability of contagion of this coronavirus. It is necessary to use linked techniques to situated learning such as working within neighborhoods, presentating specific cases of housing in the sector (with the support of digital materials and virtual spaces if possible), debates, comparison and analogies of similar cases, and practical work focused on good practices in healthy housing. Finally, it worth noting that communities are

capable of analyzing, reasoning, and criticizing on a real scenario and can motivate the application of alternatives to try to solve a public health problem related to the identified risk factors.

This gives them the possibility to assess good practices in healthy housing that could increase the desire to learn new techniques to improve their livability, reduce the rate of transmission of the COVID- 19, and strive for collaborative community work. Nobody is better than the subject who learns to know what he really knows.

Conclusions

- Promoting environmental education and community work is a fundamental part for projects related to engineering work in communities to reach a positive impact and achieve significant improvement of the quality of life. In this case, the good practices implemented aimed at healthy housing to prevent the spread of the COVID-19.

- For integrating processes to study a specific problem, it is important to associate with the communities since their participation makes the process more dynamic and results can be visible in the short term. also, working on risk factors to promote good practices in healthy housing promotes participatory processes and knowledge exchange.

- Good practices in healthy housing can integrate communities into participatory learning, which is inclusive and generated from the current reality of the territories during a pandemic situation to which they are exposed; this involvement is the reason why the promotion of healthy spaces ought to regard these communities.

- The proposal to transfer good healthy housing practices corresponds to communities' request to have solutions that are technically, economically, environmentally, and culturally sustainable. This requires educational processes aimed at communities willing to learn, so that they consider the importance of these practices for their quality of life and to prevent the spread of a virus that has such an impact to public health.

- The share expertise related to issues of public interest promotes selfless interventions from engineering, and it promotes environmental education, sanitation, and achievements of communities that have poorly planned self-built and unhealthy housing.

- The humanization of public health problems and the commitment of engineering in solving them must begin with practical community-oriented work, such as the one proposed from good practices in healthy housing. Society benefits from this, especially in those areas with scarce resources that need effective, immediate, and sustainable solutions to their problems, which in this case is COVID-19 infection.

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INVESTIGACIÓN

Homogenization Analysis in Particle Boards with Rice Husk Reinforcement

Análisis de homogenización en paneles aglomerados con refuerzo de cascarilla de arroz

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Abstract

Objective: To morphologically analyze, by means of scanning electron microscopy (SEM), agglomerated boards made from rice husk and Hidropul 400, as well as boards made from wood fibers and glue.

Methodology: For each 7,3 x 3,6 x 1,5 cm test piece, two samples were taken from the external and internal sections of each one of the boards to be analyzed. Thin-layer graphite coatings were made to each one of them, and, by means of SEM, micrographic shots were obtained in the range from 50x to 2000x.

Results: It was evidenced that the panel made from rice husk had damage to its internal structure due to its porosity, the waxy layers of its coating, the high presence of silica, and the presence of water inside the adhesive, showing irregularities in adhesion between particles and low mechanical properties.

Conclusions: Although the studied rice husk panel did not achieve the adequate structural properties, it has great applications for interior design. Additionally, due to its porous structure, its potential as a sound-absorbing material is considered. In the same way, the material can be improved by pre-treating the husk or combining it with other, more woody plant fibers such as wood waste, bamboo, coconut fiber, among others.

Keywords: SEM, agglomerate, husk, rice, homogenization, particle board

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Resumen

Objetivo: Analizar morfológicamente, por medio microscopía electrónica de barrido (SEM), tableros aglomerados elaborados con cascarilla de arroz e Hidropul 400, así como tableros elaborados a partir de las virutas de madera y pegamento.
Metodología: Para cada cada probeta de 7,3 x 3,6 x 1,5 cm, se tomaron dos muestras en las secciones externas e internas de cada uno de los paneles a analizar. Se realizaron recubrimientos de capa fina de grafito a cada una de ellas y, mediante SEM, se realizaron tomas micrográficas en rangos de 50x a 2000x.
Resultados: Se evidenció que el panel fabricado con cascarilla de arroz presentaba afectaciones en su estructura interna debido a la porosidad, las capas cerosas de su recubrimiento, la alta presencia de sílice y la presencia de agua dentro del adhesivo, mostrando irregularidades en adherencia entre partículas y bajas propiedades mecánicas.
Conclusiones: Aunque el panel a base de cascarilla de arroz estudiado no obtuvo las propiedades estructurales adecuadas, tiene grandes aplicaciones para el diseño de interiores. Además, por su estructura porosa, se considera su potencial como material absorbente del sonido. De igual forma, se puede mejorar el material al hacer un pretratamiento de la cascarilla o combinarla con diferentes fibras vegetales más leñosas como desperdicios de madera, bambú, fibra de coco, entre otros.

Palabras clave: SEM, aglomerado, cascarilla, arroz, homogenización, tablero de partículas

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INTRODUCTION

Currently, population growth and the need to satisfy its subsequent demand generates an overexploitation of natural resources while waste production increases. In this context, one of the most demanded natural resources is wood. The excessive use of this resource has caused deforestation, soil erosion, and a drop in biodiversity, which has awakened the interest of the scientific community

for implementing new materials that replace the use of wood, thus encouraging the use of natural organic matter or agricultural waste.

Colombia, due to its great biodiversity and agriculture, possesses several organic materials based on vegetal fibers such as cotton, sugarcane, fique, banana, yute, palm, and guadua, as well as a wide range of residues from wheat, rice, peanut, coconut, corn, and coffee, among others. Therefore, this country has great potential for generating high value-added products that would allow profiting and achieving significant biotechnological developments.

There are several studies at the national level based on the exploitation of these raw materials. For example, Álvarez *et al.*, 2007 analyzed the influence of a pre-treatment with banana fiber coming from the central leaf vein with the purpose of developing composed materials. Through physical-mechanical tests and SEM analyses, it was found that free radicals were generated on the surface of the lignin and that they were coupled during the high-temperature pressing process, thus generating polymerization or crosslinking, which improves material properties. Vargas-Ortiz, 2015 studied the physical and mechanical properties of Chontaduro palm fibers to determine the viability of their use as an alternative material for civil works construction, concluding that they have a great potential as reinforcement of composed polymeric-matrix and cementile materials. Cuéllar & Muñoz, 2010 studied the effect of *Guadua angustifolia* fiber with and without chemical treatment, employing sodium hydroxide over the mechanical properties of a polymeric matrix reinforced with 10 and 20 % in weight of fiber, thus concluding that it represents a viable alternative as a potential reinforcement material for polymeric matrixes.

Regarding agricultural waste, there are numerous studies that could be applied as large-scale technologies in the future. For example, Coral, 2019 made normal-concrete specimens with the addition of coffee husk vegetal fiber as a replacement for thick aggregates, which achieved a good resistance for non-structural elements. Furthermore, Segura, 2019 fabricated ceiling panels reinforced with peanut husk and eggshells. This study concluded that these panels slow down heat transference, so they contribute to maintaining rooms warm.

Colombia ranks 21^{st} in the world in the production of rice, considering that it is a fundamental product in the domestic consumption of the country (Becerra *et al.*, 2018). According to DANE and Fedearroz, rice production in Colombia is around 2.000.000 tons per year, and 400.000 of them correspond to rice husk residues, which are not used properly (Fedearroz, 2018). These residues are generally used as fuel to be burned in grain drying processes, and commercialized for use in aviculture, gardening activities, among others. Therefore, given the biomass available in the country, there is currently an insufficient capacity for the total consumption of this product.

In Colombia, research on the use of agricultural residues as reinforcement of the polymeric matrix on composed materials has been focused on the physical and mechanical properties of rice husk. As an example, Serrano *et al.*, 2012 used rice husk with and without pretreatments to manufacture light mortars, finding that, due to the morphology and water absorption of rice husk, the elaboration of composites based on it requires the addition of tensoactive substances to the mixture. These mortars

reached densities in the range of 1,1-1,3 g/cm^3, with mechanical resistances between 2 and 4 MPa, which led to conclude that they do not have the mechanical properties of traditional mortars and concretes, although they can still be utilized as light construction components. Proaños & Sandoval, 2010 manufactured compression-resistant acoustic panels made of rice husk, cement, and sand. They established the technical feasibility of rice husk as an insulating material, given its ability to reduce sound. These panels constitute an alternative for users with fewer resources in the acoustic insulation of homes. Gutiérrez-M.D. *et al.,* 2014 treated rice husk using starches to obtain a material with adequate physical stability, without affecting its insulating capacity. They found that the composed material shows a good resistance to bending. Bedoya-Hincapié *et al.,* 2009 developed the prototype of an agglomerated composed material based on products from the coffee axis (Colombia), such as rice husk, clay, sand, and aloe gel, thus establishing that its mechanical and thermal properties are close to those of Sajo, Ciprés, Machare, or Nogal Cafetero woods; the agglomerated material showed a modulus of elasticity similar to those of the aforementioned wood species.

Although there are several studies that characterize physical and mechanical properties, there are very few that have thoroughly analyzed the distribution, homogenization, and internal structure of the particles and fibers within these materials, as well as their interaction with different adhesives and binders used in chipboard manufacturing. Analysis through homogenization allows identifying the properties of composed materials that cannot be determined by mechanical tests, since it is necessary to observe the behavior of the materials within their structure by using different technologies such as optical microscopy, scanning electron microscopy, and other advanced methods that include X-ray spectrometry and confocal scanning (Alemdar *et al.,* 2008, Badel *et al.,* 2008).

Some international researchers, such as (Kurokochi & Sato, 2015a), have analyzed the internal structure of rice husk panels, mainly finding that their porous structure drastically affects its strength due to the presence of trichomes and silica protuberances, as well as a thin layer of wax that prevents the particles from making contact with each other. (Hwa-Hyoung & Kie-Sun, 200) found that the elaboration of a composed board with husk reinforcement required eliminating the trichomes and silica to achieve a significant increase in its mechanical properties. Their research evinced that the panel contained less lignocellulosic materials and more ashes and extracts with lighter-than-wood molecular weights. Its hollow structure also affected the non-uniform resin distribution, thus resulting in a disrupted glue line between the particles (Zhang *et al.,* 2011). The high content of ashes, mainly silica, also contributed to the non-uniform resin distribution (Hiziroglu & Suzuki, 2007). Due to this porous structure, panels composed of rice husk and sawdust are considered for their potential as sound-absorbing materials (Kang *et al.,* 2012).

In light of the above, the purpose of this research is to analyze homogenization through scanning electron microscopy (SEM), as well as to acquire data on the typology of external and internal surfaces, weave organization, and particle distribution of a board manufactured from rice husk and Hidropul water-based binder. A comparison with a traditional wood-based board is made, highlighting main differences and similarities contributing to accept or improve the studied material.

METHODOLOGY

Materials

For the homogenization analysis, two types of boards with adhesive resins were selected: one made from rice husk and the other from wood fibers. These boards were of medium density. The rice husk board was manufactured from a fine selection of particles coming from the mills and processing plants of the municipality of Espinal, Tolima, Colombia. The selected residue was free of impurities, with an average size of 4 to 12 mm. The binder used was Hidropul 400 HTR (water-based polyurethane glue) plus a vulcanizing agent (AQ212 Polyisocyanate) for wood obtained from the Pegaucho S. A. company (Alféres-Rivas, 2017). Table 1 presents the physical and mechanical properties of the board agglomerated from rice husk.

For the agglomerated board made from wood fibers and adhesive resin, the manufacturer Celulosa Arauco S. A. was selected. This panel is of general use in dry environments, with physical properties that meet the MDF standard. Table 2 presents the physical and mechanical properties of the wood fiber agglomerated board.

Table 1. Technical sheet for the rice husk agglomerated board

TECHNICAL SPECIFICATIONS			
PRODUCT	**DIMENSIONS**		
RICE HUSK PARTICLEBOARD-HIDROPUL-400HTR	THICKNESS(mm)	LENGTH(m)	WIDTH(m)
	15	2,44	1,83
	TOLERANCES		
	THICKNESS(mm)	LENGTH(mm)	WIDTH(mm)
	+/- 0,2	+/- 2	+/- 2
PHYSICAL MECHANICAL PROPERTIES			
PROPERTY	**UNIT**	**VALUE**	
Density	Kg/m^3	649,3	
Internal Bond	N/mm^2	0,7	
M.O.E	N/mm^2	2.140,8	
M.O.R	N/mm^2	15,67	
Edge	N	1.033,97	
Side	N	1.447,95	

Source: Authors.

Table 2. Technical sheet for the commercial agglomerated fiber board (MDF-Arauco)

TECHNICAL SPECIFICATIONS			
PRODUCT	**DIMENSIONS**		
ARAUCO STANDARD MDF- ADHESIVE RESIN	THICKNESS(mm)	LENGTH(m)	WIDTH(m)
	15	2,44	1,83
	TOLERANCES		
	THICKNESS(mm)	LENGTH(mm)	WIDTH(mm)
	+/- 0.2	+/- 2	+/- 2
PHYSICAL MECHANICAL PROPERTIES			
PROPERTY	**UNIT**	**VALUE**	
Density	Kg/m^3	680	
Internal Bond	N/mm^2	0,7	
M.O.E	N/mm^2	2.400	
M.O.R	N/mm^2	28	
Swelling	%	<11	
Edge(N)	Kg	>85	
Side(N)	kg	>105	

Source: Authors.

From the selection of agglomerated boards, as well as from the technical information supplied by the manufacturers, the homogenization analysis of agglomerated particles was performed.

Morphology (SEM)

Observations were conducted on the probe specimens of both board types using a FEI QUANTA 200 scanning electron microscope property of Universidad Nacional de Colombia, Bogotá branch. Two samples were taken from each panel, corresponding to the internal and external surfaces of the material, which allowed understanding the morphology and homogenization of the particles. The samples were subjected to a thin layer coating of graphite approximately 0,1 mm thick in order to achieve current conductivity between them. The SEM images were analyzed on various scales in a range from 50x to 2000x. The equipment was calibrated for 50x to 2,00 mm, and for 2000x to 50 μm.

RESULTS

Morphological analysis of the rice husk and Hydropul 400 panel (external section)

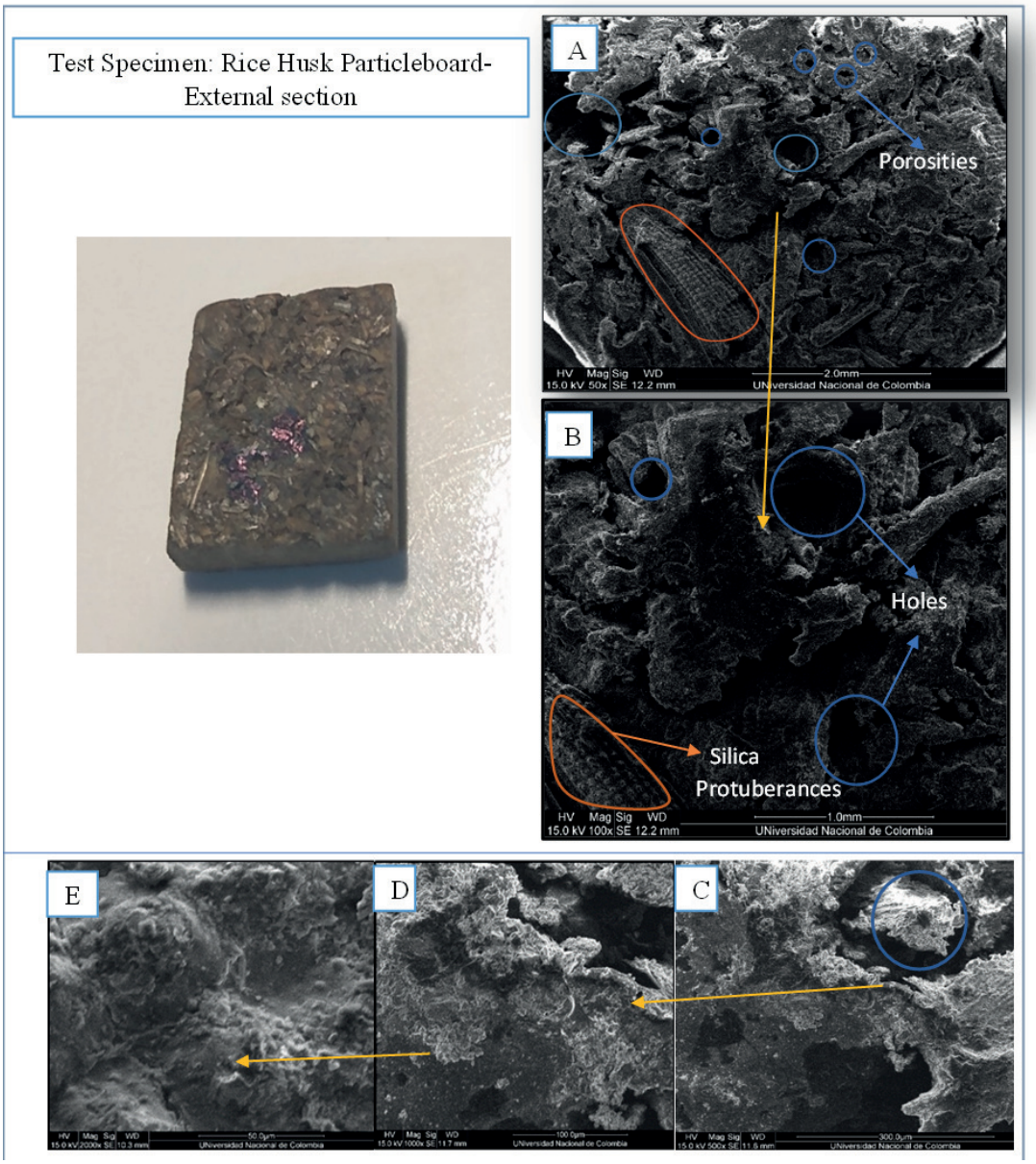

Figure 1. SEM micrographs of the external section of the rice husk + Hidropul 400 panel Magnification: A (50x, 2 mm); B (100x, 1 mm); C (500x, 300 μm); D (1000x, 100 μm); E (2000x, 50 μm)

Source: Authors.

Figure 1 shows the morphological state of the external section of the panel. The probe specimen was brought to dimensions of 11 x 8 x 4 mm. The micrographs were taken from the upper face of the specimen. Figure 1a presents the structure from a general perspective, and Figure 1b is a detail of 1a at a 100x larger scale and shows a uniform dense mass throughout the structure, with some holes due to the fact that the rice husk did not completely cover the spaces during hot pressing. Likewise, in the lower zone of the Figure, it is possible to see the rice husk abaxial or the external surface of the exocarp, which is characterized by a symmetrical structure constituted by convex cells, separated by furrows, and grains composed of silicon that are dispersed over the entire surface (Arcos *et al.*, 2007). Although porosities are observed within the structure, the sample externally presents a good packing of the particles.

In Figures 1c, d, and e, observations were made on the same sample, but with larger scales. Figure 1c was taken at a 500X scale with a calibration of 300 µm. The inner portion of this Figure (indicated inside the circle) corresponds to the section of pressed husk covered with adhesive (Hidropul 400), and the white phase corresponds to adhesive extending along the ends of the irregular surface. Finally, the dark-colored phases correspond to the rice husk particles.

In Figure 1d, a portion of 1c is observed with a scale of 1000x, presenting the same characteristics. As for Figure 1e, in which the magnification is 2000x, dome-shaped protrusions are observed, which correspond to the silica from the shell covered by uniformly dispersed adhesive with micro-cracks in its grooves. This characteristic may be present when the used adhesive ages.

Morphological analysis of the rice husk and Hidropul 400 panel (internal section)

Figure 2 presents the morphological state of the internal section of the panel; it is the SEM micrograph of the panel's structure, which is obtained at a depth of 5 millimeters from the outer surface. Figure 2a shows porosities because the shell was not properly packed during hot pressing. Some of these holes (yellow circles) tend to be characterized by having smooth inner surfaces, which, in this case, corresponds to bubbles (Serrano *et al.*, 2012). These could be formed by the mixture of adhesive (Hidropul 400) and the vulcanizing agent.

The internal agglomeration shows a non-homogeneus particle distribution due to the large number of irregularities and structures that collapsed under heat and pressure during pressing. de Barros Filho *et al.*, 2011 argue that the number of collapsed thin-walled fibers depends on the degree of damage caused by hot pressing, which could lead to more intimate contacts between fiber and matrix. This results in a better union and compaction in between fibers. Moreover, the collapse of the cell walls can cause more mechanical damage, such as a reduction in the rupture modulus and, in some cases, an increase in the thickness of the agglomerated piece.

Figures 2b, c, d, and e correspond to the internal samples of the test probe. These shots were taken at larger scales (100x, 500x, 1000x and 2000x, respectively). In Figure 2b, porosities that can be produced by a poor bond between particles and adhesives are observed. Likewise, the distribution

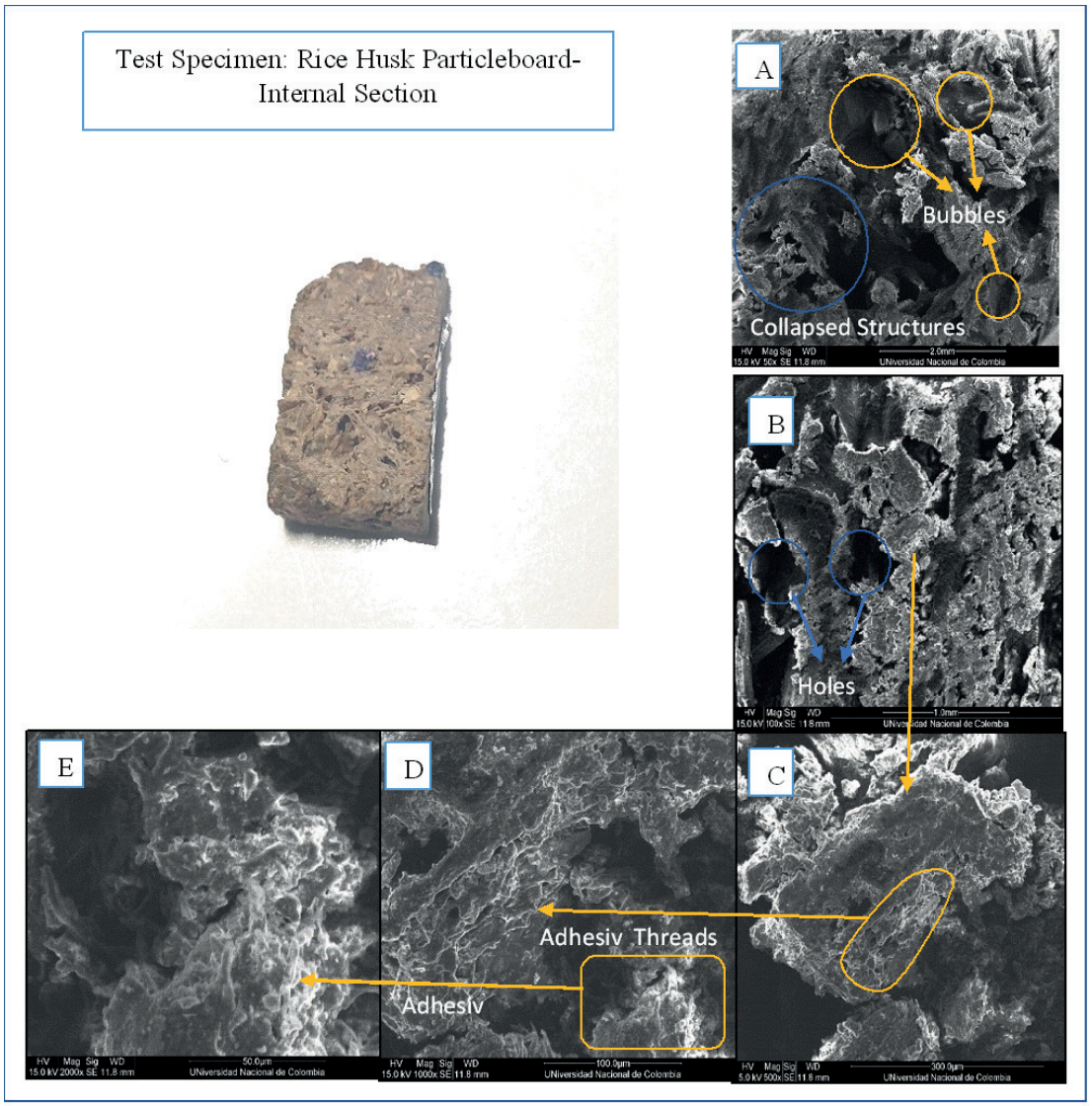

Figure 2. SEM Micrographs of the internal section of the rice husk + Hidropul 400 panel Magnification: A (50x, 2 mm); B (100x, 1 mm); C (500x, 300 μm); D (1000x, 100 μm); E (2000x, 50 μm)

Source: Authors.

of the adhesive throughout the surface (white phase) can be seen in less detail. It was also present in a greater proportion, tending to agglutinate at the edges of the surface of the compressed husk flakes.

Figure 2c presents a detailed view of a portion of Figure 2b, where the surface of the pressed husk fibers is shown with a high concentration of adhesive at their ends. This due to the fact that the adhesive penetrated mainly between the fiber walls' regions and irregularities. In wood agglomerates, the penetration of the adhesive between cell walls and intermolecular spaces is important since it invol-

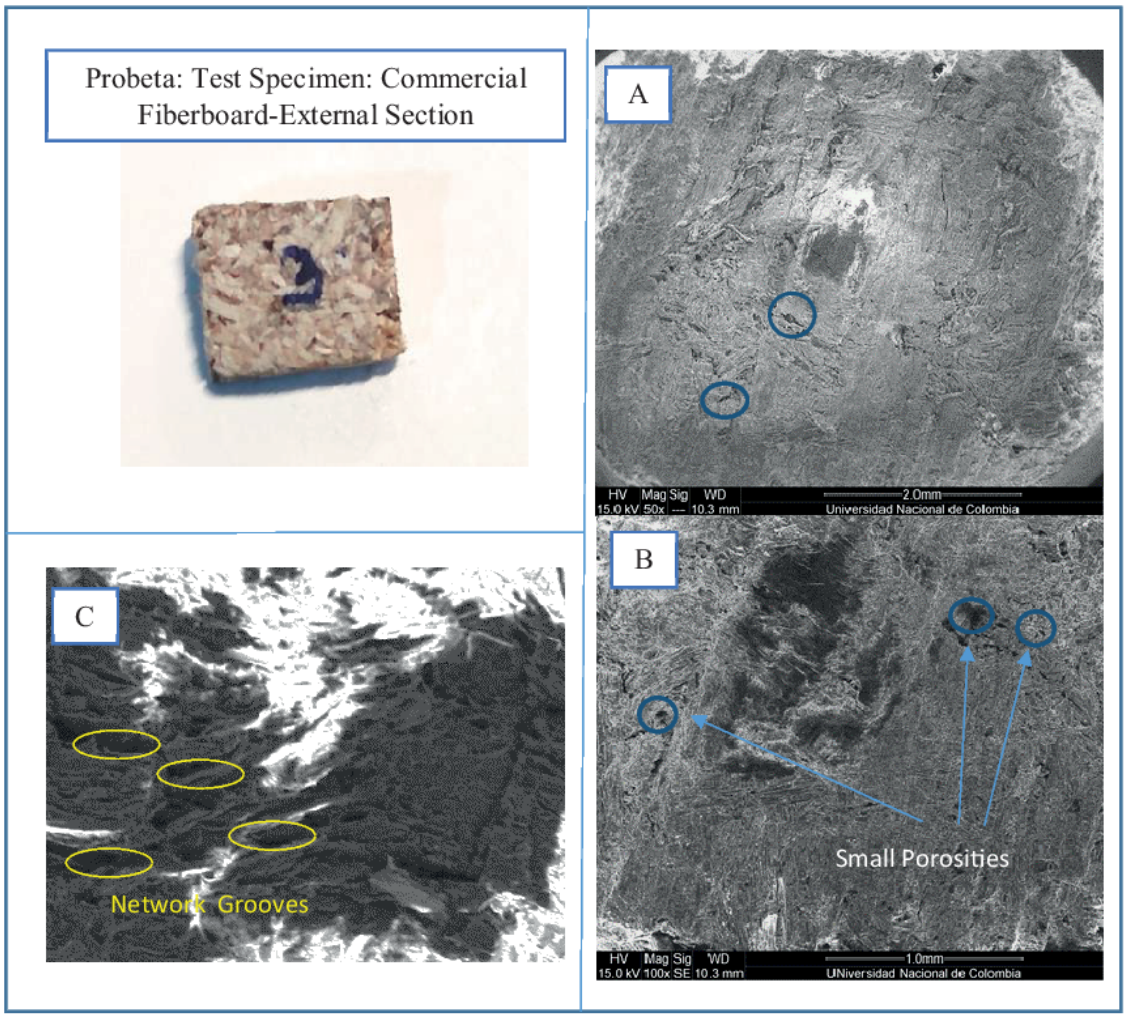

Figure 3. SEM micrographs of the external section of the commercial agglomerated panel Magnification: A (50x, 2 mm); B (100x, 1 mm); C (500x, 300 μm)

Source: Authors.

ves both physical and chemical bonds, which strengthens the adhesive bond (Singh *et al.*, 2015). For this reason, the possibility of this same behavior for the rice husk particle board could be evaluated.

Figure 2d refers to 2c with a 1000x scale, which allows the detailed visualization of the cavities and porosities present in the sample, clearly showing the layers of rice husk and adhesive, which were applied simultaneously, one on top of another. Therefore, through hot pressing, its final sandwich structure (Figure 2c) managed to form a better bond with the rice husk fiber, as well as a uniform distribution in ad hesive threads. The manufactured sandwich structure, using compression molding techniques, allows the fabricated material to be lightweight with practical mechanical properties (Li *et al.*, 2010).

Figure 2e presents a portion of 2c at a scale of 2000x, in which the binder impregnated in the husk nanoparticles is visualized at a higher concentration, due to penetration and absorption into the irregular parts and walls. As explained in Figure 2b, there is better wetting in the fibers by the adhesive, observing a tendency towards heterogeneous distribution as a consequence of a higher binder content in this section.

Morphological analysis of commercial fiberboard (MDF-Arauco) (external section)

Figure 3 shows the external section of the commercial fiberboard, with sample dimensions 10 x 9 x 4 mm. Figures 3a and b show very good homogenization and distribution of particles with very small porosities on the surface and only a few roughnesses, thus allowing the visualization of a good compaction technique. Surface characteristics in terms of roughness play an important role in determining product quality of commercial MDF. The degree of surface roughness depends on the characteristics of the raw material, such as species, particle size, fiber distribution; as well as on manufacturing variables, including pressing parameters, resin content, and other processes (Hiziroglu & Suzuki, 2007). This shows the high-quality standards with which the panel was manufactured.

In Figure 3c (500x scale), the porosities become more evident, although they remain generally small and of homogeneous size. Moreover, cell walls are distinguished between wood fibers, forming elongated grooves that establish a network of wood fibers oriented in the direction of the cavities between cell walls. (Sliseris *et al.*, 2016) state that a slight difference in the orientation of fiber can significantly affect the mechanical properties of MDF, so it is concluded that the panel shows good properties if oriented in a single direction.

Morphological analysis of commercial Fiberboard (MDF-Arauco) (internal section)

Figure 4 corresponds to the sample from the internal structure of the commercial agglomerated fiberboard, with a depth of 5 mm from the external surface. Figure 4a shows an almost compact structure, which contributes to a homogeneous distribution and a better interfacial bond, thus improving the mechanical properties of the material (Madyan *et al.*, 2020). Although valleys are observed on the surface, they are due to the geometry formed between fibers. As for the porosities, given their size, they are almost imperceptible at this scale.

In Figure 4b, due to the increase in scale (100x), the valleys, as well as some porosities observed in 4a, become more evident. In the same way, the cell walls can be seen in more detail, with large volume that is slightly collapsed. This contributes to the good resistance of the wood particles against pressing, thus obtaining good flexural properties (de Barros Filho *et al.*, 2011). In another zone of this micrograph, the wood is seen to take the form of threads (gray circle). These are a result of the detachment of particles when taking the sample from the original test piece, which means that they are very well embedded into the matrix of the agglomerated panel. As for the adhesive, the resin is

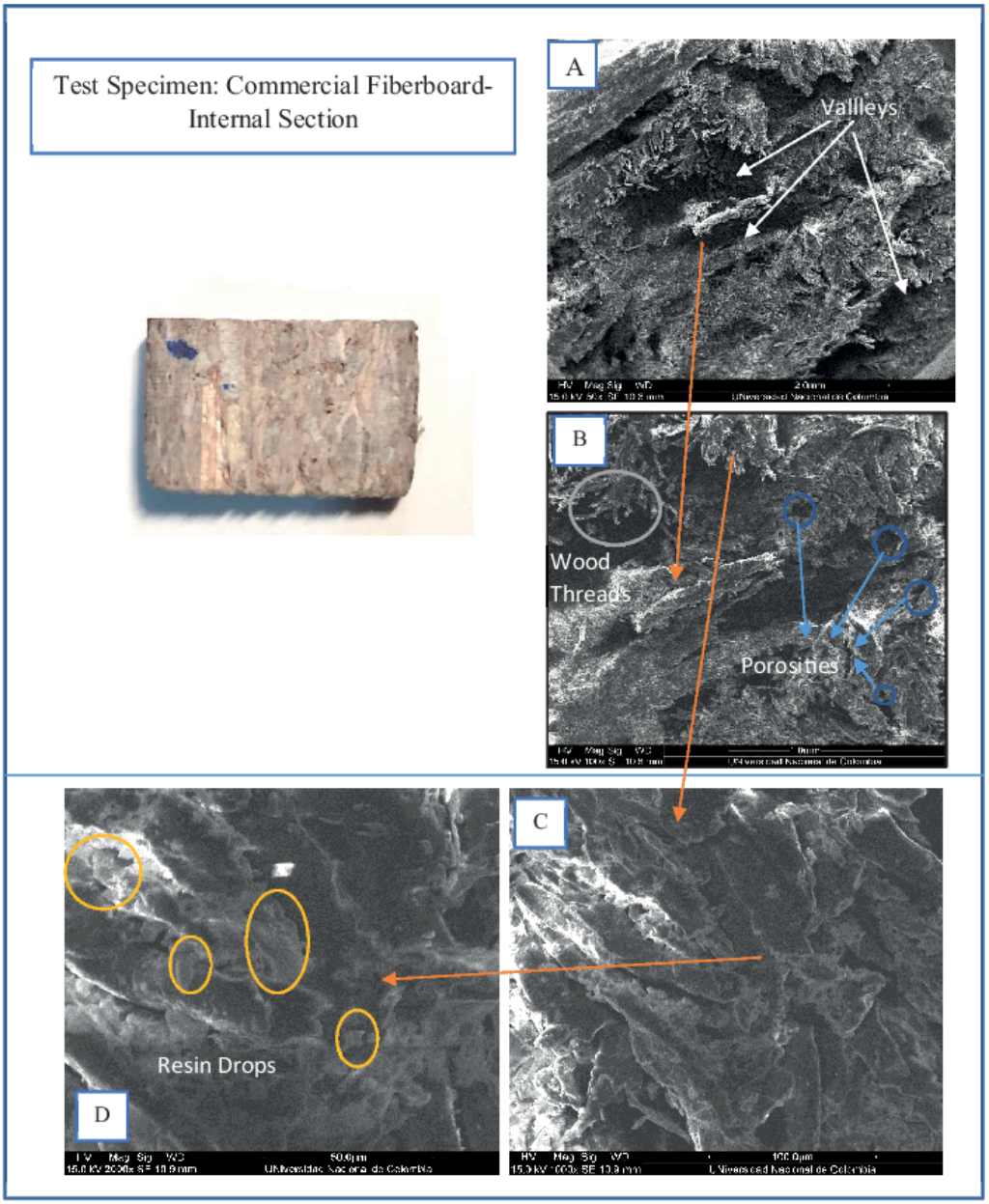

Figure 4. SEM micrographs of the internal section of the commercial agglomerated panel Magnification: A (50x, 2 mm); B (100x, 1 mm); C (1000x, 100 μm); D (2000x, 50 μm)

Source: Authors.

detailed as the bright spots that are distributed at a greater concentration at the ends of the chips, particles, and cracks. However, in general terms, they are equally dispersed throughout the entire surface of the sample.

Figure 4c shows the zoned detail of 4b (a part of a chipped surface), clearly distinguishing thin and long wood chips with good contact between them. The adhesive is distinguished by its white phase at its ends, covering the spaces between particles. The formation of interlocking networks by the particles can be observed. In general, the amount of adhesive distributes equally without excessive concentrations.

Figure 4d shows the drops of adhesive in more detail, concentrated mainly in the cracks between chips, with flat and cylindrical shapes of equal size and small and thin particles in a lower proportion, where the adhesive tends to concentrate in larger quantities. According to previous research, fine particles tend to absorb much of the resin in the particleboard (Evans *et al.*, 2010).

Discussion

By comparing the external section of both materials on the same scales (50x and 100x), it was determined that the commercial fiberboard presented a surface without holes and small porosities, whereas the rice husk particleboard showed greater irregularities, holes, and large porosities. It should be noted that both materials were manufactured in specialized plants for the manufacture of MDF. Therefore, they were subjected to high manufacturing standards. For Abdul Khalil *et al.*, 2010 and Fiorelli *et al.*, 2019, a greater contact between fibers during hot pressing reduces the content of holes and porosities, thus yielding a higher material density. This is why, when reviewing the corresponding technical sheets of the commercial and rice husk boards, densities of 680 and 649 kg/m^3 are found, respectively. This suggests a relationship between the resulting imperfections of the rice husk board and its low density. According to the literature, this is due to the silica in the form of grains (as observed in Figure 1b) and a thin layer of wax, which prevent penetration of the adhesive (Hidropul 400) to bind with the hydroxyl groups of cellulose present in the husk (Cheng *et al.*, 2004, El-Kassas & Mourad, 2013, Zheng *et al.*, 2009).

Regarding the external distribution of the adhesive, the large amount of Hidropul 400 resin (white phase in Figure 1c) used in the rice husk board becomes evident when comparing the two materials, since no adhesive resin is observed at the same scale (500x) in the commercial board; a closer approach (1000x) to its internal part is therefore necessary to observe resin particles. For this reason, it was determined that the amount of adhesive in the husk board is greater than in the commercial one. Therefore, a greater amount of resin is needed for adequate penetration between particles, since mechanical properties improve by increasing the levels of adhesive (Ye *et al.*, 2007). However, rice particleboards do not have commercial acceptance due to the substantially higher amounts of adhesive required to acquire acceptable properties (Kwon *et al.*, 2013).

The homogenization and distribution of particles on the external surface of the commercial board is superior to that of the rice husk. This is due to the fact that it shows a strong and well-organized fiber network structure, unlike the rice husk, represented only by a compact mass. The reason for

this is the size of the wood fibers, which are finer and lengthier than rice particles (Kang *et al.*, 2012). According to (Battegazzore *et al.*, 2018), fiber boards have proved to be more rigid than particleboards, thus indicating their ability to maintain more than three times the load. This means that the shape of the raw material affects its mechanical properties.

The internal section of the rice husk panel is more irregular than its surface, as it has a large number of holes and larger porosities. Likewise, the commercial panel has a different internal structure since it is more compact and less fibrous than on its external side. However, the large amounts of internal imperfections present in the rice husk panel are due to the silica and wax present in the husk, thus causing the adhesion between particles to be poorer internally than externally. This is because, internally, there are more layers of husk. Moreover, at the time of hot pressing, the press acts directly over the panel's surface, making the adhesion better on the surface. The size of the holes present is due to the fact that the rice particles, being wider, form holes of greater dimensions than those formed by the wood fibers (Kang *et al.*, 2012).

Wood and rice husk, as well as other plant fiber materials, are considered lignocellulosic materials, which consist mainly of three chemical components: cellulose, hemicellulose, and lignin. They are responsible for the mechanical, structural, and durability behavior, thus giving good resistance, rigidity, and stability to the fiber (Sánchez *et al.*, 2017). A high content of these components has desirable properties for use as reinforcement in composite materials (Bogoeva-Gaceva *et al.*, 2007). As the amounts of cellulose and lignin are lower in husk than in wood, they make the rice board supports lower pressure at the moment of hot pressing. Consequently, the fiber walls collapse in a greater degree than rice husk. This is due to its non-homogeneous structure, as discussed in the results section. It is important to mention that, due to their porous structure, particleboards that comprise only rice husk have 1/3 of the strength of wood-based particleboards (Kang *et al.*, 2012).

Internally, at scales of 1000x and 2000x, the distribution of adhesives in both materials could be observed in more detail, where the wood-based panel obtained a better distribution of resin without excessive concentrations and in the form of drops, unlike the adhesive (Hidropul), which tended to agglutinate in great quantities on the irregularities of the cell walls of the husk. Therefore, a large mass of glue was observed, due to the large amount of adhesive used. Additionally, a greater number of voids and porosities causes a greater consumption of adhesive, which consequently restricts adequate contact between particles with lower IB (internal bond) (Klímek *et al.*, 2017). It is worth noting that water-based adhesives such as Hidropul 400 decrease wettability by interacting with the thin waxy layer, thus influencing the quality of the bond (Kwon *et al.*, 2013). According to Li *et al.*, 2010, oil-based adhesives such as diphenylmethane diisocyanate (MDI) or polymeric diphenylmethane diisocyanate (PMDI) are generally used to make high-quality straw-based particleboards.

As discussed above, the low properties of the board are evident judging from the homogenization and SEM structural analyses, which is complemented by the values found in the main mechanical tests of each material listed in the technical sheets (Tables 1 and 2), when comparing the rice husk boards with the traditional wood boards. Regarding their MOE (moudulus of elasticity), values of

2.141 and 2.400 N/mm^2 were obtained. In the same way, when comparing their MOR (modulus of rupture), resistances of 28 and 15,67 N/mm^2 were obtained, respectively. The low resistance to rupture of the husk board was made evident, which is why it is not recommended for use as construction material that supports structural compression loads. The porous structure present within the particleboard presents sound absorbing characteristics. Uses for this material could be valued in wall cladding, ceiling panels, or other settings that require sound absorption properties, but do not require robust mechanical properties, as well as other non-structural applications such as furniture and interior accessories (Kang *et al.*, 2012).

Regarding the improvement of the studied rice husk board, and based on previous research, husk pretreatments are said to decrease the amount of silica and eliminate the wax layer. These include heat treatment, steam explosion (Ndazi *et al.*, 2007), acid or alkali treatment (Ajiwe *et al.*, 1998), and the combination of alkaline treatments with hydrogen peroxide or bleaching (Salam *et al.*, 2007, Wójciak *et al.*, 2007). However, in these studies, although the properties of rice husk increased, they did not reach the potential of wood-based boards after treatment. Additionally, there is still a high adhesive addition (Li *et al.*, 2013, Zhang & Hu, 2014). It is also possible to improve the material by combining it with more woody fibers such as wood, bamboo, coconut fiber, and other residues (Hiziroglu & Suzuki, 2007, Yang *et al.*, 2003, Zhang & Hu, 2014). All of these works concluded that they could be used as structural materials when they acquire the same capacities as commercial panels, since few amounts of resin are required. Another recent study suggests the manufacture of panels without binders by hot pressing, where the silica trichomes were removed by a very fine grinding, and the wax was removed by extraction with organic solvents. However, these panels did not meet the technical specifications of MDF (Kurokochi & Sato, 2015b). In light of the above, for future research, it is suggested that several of these techniques be combined for the improvement of the studied material.

Conclusions

The board made from rice husk particles and Hidropul 400 HTR showed a low resistance in comparison with wood-fiber boards. This is due to its porous structure and its low bonding strength between particles, as well as to the silica and waxy layer present in the material.

The large amount of porosities influenced the low density of the rice husk board and, therefore, its low properties.

The rice husk particleboard used a higher amount of water-based adhesive compared to the commercial fiberboard, thus clumping mostly in its irregularities. However, this was not enough, as it did not completely cover the holes.

The packing and distribution of particles was better in the wood-based panel than in the husk one, due to the shape of its lengthier and thinner fibers, which formed well-established networks. Furthermore, its higher content of cellulose and lignin gives the fiber strength and rigidity to withs-

tand greater pressure during the hot pressing procedure and avoid the collapse of its cell walls. The rice husk panel lacked these properties.

The use of a water-based adhesives such as Hidropul 400 HTR prevents penetration by interacting with the waxy layer of the rice husk, which is why, to improve the material, the use of an oil-based binder for the manufacturing of agglomerated rice husk panels is recommended for future research.

Although the studied rice husk board did not achieve adequate resistance properties for working as a structural material, it has great applications for interior design, due to its acoustic absorption and its low weight. Furthermore, because it was manufactured from small particles in a specialized plant, it has a great surface finish.

For the improvement of the studied rice husk panel, some of the different techniques evaluated for the pretreatment of rice husk can be implemented to eliminate the silica grains and wax, in combination with other types of natural fibers that contain larger amounts of lignin and cellulose such as bamboo, coconut fiber, and other residues, in addition to the use of equipment for the manufacturing of MDF in specialized plants, thus acquiring the properties of traditional fiberboards.

These results were obtained by performing homogenization analysis by means of SEM micrographs in combination with information from the literature. They are consistent with the properties found quantitatively in the different mechanical tests, which makes these types of analysis helpful when observing the structural behavior of any material.

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INVESTIGACIÓN

Método para evaluación de una estrategia de control realimentado en la funcionalidad de agarre de poder con una prótesis de mano robótica

Method for the assessment of a feedback control strategy on the power grasp functionality with a prosthetic robotic hand

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Resumen

Objetivo: En el diseño de una prótesis de mano robótica surgen variedad de problemáticas para las cuales existen múltiples soluciones propuestas en la literatura. Una de las problemáticas es la selección de una estrategia para el control automático del movimiento de la mano. Entre las funcionalidades de una prótesis, la de *agarre de poder* es una de las más importantes. Dada la gran cantidad de propuestas en cuanto técnicas de control para el agarre de poder, el diseñador se enfrenta al dilema de cuál de ellas es la más adecuada para su diseño particular. Aunque hay métricas para cuantificar la calidad del agarre, las que se han propuesto abordan diversos aspectos de manera independiente, lo cual no permite tomar una decisión acerca de la mejor opción para el caso particular. En este trabajo se propone un método para calcular un indicador compuesto que permite la evaluación del desempeño de técnicas de control en el agarre de poder, con base en las siguientes métricas individuales que evalúan diferentes aspectos en la ejecución del agarre de poder: la fuerza del dedo, la fuerza del agarre, la eficiencia del agarre, el tiempo de ciclo de agarre, la resistencia al deslizamiento, el error de seguimiento y el sobreimpulso de la respuesta transitoria. Gracias al método propuesto en este trabajo, se da respuesta a la pregunta: "De varias opciones de control a probar, ¿cuál ofrece un mejor desempeño funcional?".

Metodología: Se adoptó un conjunto de métricas con las cuales obtener datos cuantitativos relacionadas con la calidad del agarre de poder y con el desempeño del objetivo de control para gobernar la prótesis. Posteriormente, se calcularon métricas individuales seleccionadas para cada una de las técnicas de control de agarre a evaluar, sobre un entorno virtual, constituido por una mano robótica y un objeto a agarrar. Luego se construyeron dos indicadores compuestos para obtener una valoración cuantitativa de la calidad del agarre a partir de un análisis estadístico, y se contrastaron los resultados contra las métricas individuales utilizadas.

Resultados: Se planteó un método para la construcción de un indicador compuesto que permitiera la evaluación del desempeño de técnicas de control, en agarres de poder en manos robóticas. Al implementar dicho método, se encontraron los mejores valores de desempeño en controladores híbridos.

Conclusiones: En este trabajo se sugiere una alternativa tendiente a facilitar la toma de decisiones del diseñador en cuanto

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a la técnica de control más adecuada, entre varias disponibles, para el logro del agarre de poder con una prótesis específica. El método busca construir un indicador compuesto que agrupa variadas métricas para evaluar funcionalidad particular de agarre, y también para cuantificar el logro de seguimiento de consignas, facilitando la toma de decisiones acerca de la incidencia de la técnica de control en el logro del objetivo final.
Financiamiento: Este trabajo fue financiado por la Universidad del Cauca, en el marco del programa de Maestría en Automática.

Palabras clave: mano robótica protésica, agarre de poder, indicadores compuestos, evaluación de la calidad del agarre de poder.

Abstract

Objective: In the design of a robotic hand prosthesis, a variety of problems arise for which there are multiple solutions proposed in the literature. One of them is the selection of a strategy for the automatic control of the movement of the hand. Within the functionalities of a prosthesis, the power grip functionality is one of the most important. Given the wide variety of proposals in terms of control techniques for power grip, the designer is faced with the dilemma of which of them is the most suitable for his particular design. Although there are metrics to quantify the quality of the grip, those that have been proposed address various aspects independently, which does not allow making a decision about the best option for the particular case. In this work, a method is proposed to calculate a composite indicator that allows the evaluation of the performance of control techniques in the power grip based on the following individual metrics that evaluate different aspects in the execution of the power grip: finger strength, grip strength, grip efficiency, grip cycle time, slip resistance, following error, and transient response overshoot. Thanks to the method proposed in this work, the question is answered: of several control options to be tested, which one offers better functional performance?
Methodology: A set of metrics are adopted with which to obtain quantitative data related to the quality of the power grip and to the performance of the control target to govern the prosthesis; subsequently, selected individual metrics are calculated for each of the grip control techniques to be evaluated on a virtual environment, consisting of a robotic hand and an object to be grasped; then two composite indicators are constructed to obtain a quantitative assessment of the quality of the grip based on a statistical analysis, and the results are contrasted against the individual metrics used.
Results: A method is proposed for the construction of a composite indicator, which allows the evaluation of the performance of control techniques, in power grips in robotic hands. By implementing this method, the best performance values were found in hybrid controllers.
Conclusions: In this work, a method has been proposed to facilitate the decision-making of the designer regarding the most adequate control technique, among several available, to achieve the power grip with a specific prosthesis. The method seeks to build a composite indicator that groups together various metrics to evaluate particular grip functionality, and also to quantify the achievement of following instructions, facilitating decision-making about the incidence of the control technique in the achievement of the final objective.
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Keywords: prosthetic robotic hand, power grasp, composite indicators, quality of power grasp assessment.

Tabla de Contenidos

Introducción

Las manos humanas tienen una estructura difícil de imitar con una prótesis robótica debido al número de grados de libertad disponible, el número de músculos que gobiernan sus movimientos, los mecanismos de percepción sensorial y su compleja comunicación con la actividad cerebral. La tarea de agarre de objetos es una de las funciones más complejas a ser reproducida por un sistema robótico, y una de las funcionalidades más importantes que el usuario desea recuperar (Boughdiri *et al.*, 2012). Usando la taxonomía de Napier, el agarre se puede clasificar en dos tipos: poder y precisión; este último ocurre cuando el objeto queda atrapado entre los flexores de los dedos y el pulgar opuesto, y el agarre de poder implica sostener un objeto en la cavidad formada por los dedos flexionados y la palma de la mano, aplicando una contrapresión con el pulgar en el plano de la mano (Napier, 1956).

El problema del agarre de objetos con manos robóticas suele dividirse en dos fases: síntesis de agarre, en el cual se estiman los puntos de contacto entre la mano y el objeto, así como también la fuerza que garantice un agarre estable; y ejecución de agarre, la cual se divide a su vez en una fase antes del contacto y una fase después del contacto. Para evaluar el agarre en manos robóticas, se definen métricas de calidad, las cuales se utilizan en la evaluación, comparación y selección de las configuraciones de agarre. En Rubert, León, *et al.*, 2017 se utilizan las métricas en la fase de síntesis de agarre, a manera de guía en algoritmos de planificación de agarre. En otros casos se implementan las métricas en la evaluación de diferentes aspectos de las manos robóticas, como la ubicación de puntos de contacto, o fuerzas de contacto frente a perturbaciones y manipulación del objeto Rubert y Morales, 2016. En ellas se analizan y caracterizan parámetros operativos que permitan la ubicación de puntos de contacto y configuración del manipulador, en aplicaciones prácticas León *et al.*, 2014.

Los trabajos de Goins *et al.*, 2014, y Rubert, Kappler *et al.*, 2017 también han implementado métricas en algoritmos de predicción de la calidad del agarre, relacionadas con los puntos de contacto, su ubicación y distancia entre estos.

También se han implementado métricas en la evaluación del desempeño de manos robóticas, comparando diferentes aspectos de diseño que conduzcan a mejorar su rendimiento (Rubert *et al.*, 2014). Recientemente el National Institute of Standars and Technology propuso un marco unificado con el mismo fin, dada la necesidad de definir marcos generales que permitan evaluar el desempeño de un diseño de mano particular en el agarre de objetos (Falco *et al.*, 2018).

A pesar de los avances en la evaluación de manos robóticas mediante variadas métricas de desempeño, no se han contemplado métricas para evaluar el desempeño de controladores automáticos para el agarre de objetos, puesto que comúnmente los controladores propuestos se evalúan en cuanto al logro del seguimiento de consignas de fuerza o posición, mas no en cuanto al desempeño del agarre del objeto. De este modo, un diseñador no tiene claridad en cuanto a qué estrategia de control, de entre las muchas opciones disponibles, es la más adecuada para el logro de un mejor desempeño del agarre.

En este artículo se contribuye al problema descrito previamente, proponiendo un método para cuantificar la incidencia que tiene la estrategia de control realimentado utilizada en el agarre de poder con una prótesis de mano robótica. Para ello se construye, de manera metodológica, un índice compuesto que permite cuantificar la efectividad de una determinada estrategia de control en el logro del agarre de poder buscado con la prótesis. El aporte central de este trabajo investigativo es que el método propuesto permite tener un indicador para concluir acerca de qué estrategia de control, entre varias implementadas, logra el mejor desempeño funcional en cuanto a agarre de poder.

Método para valoración comparativa de estrategias de control

Para dar respuesta a la problemática presentada se debe adoptar un marco de referencia para cuantificar el desempeño del agarre de poder. Para ello se propone un método compuesto por tres fases: la primera consiste en la adopción de un conjunto de métricas con las cuales obtener datos cuantitativos relacionadas con la calidad del agarre de poder y con el desempeño del objetivo de control para gobernar la prótesis; la segunda consiste en el cálculo de las métricas individuales seleccionadas para cada una de las técnicas de control de agarre a evaluar; y la tercera, la construcción de un indicador compuesto que arroje una valoración cuantitativa del agarre logrado, y con base a este indicador, evaluar las técnicas de control.

A continuación, se describen las fases del método propuesto, describiendo el cómo se implementaron para los datos de validación de este artículo en un entorno virtual. El hecho de validar el método mediante modelos virtuales permite que los resultados puedan repetirse en igualdad de condiciones, sin la presencia de los efectos externos al método que podrían ocurrir en un montaje real, según la naturaleza comparativa del procedimiento.

Fase 1. Métricas para calidad de agarre y desempeño de la estrategia de control

Se deben definir las métricas a implementar y que aporten información de la calidad del agarre y del seguimiento de consignas en agarres de poder. Se debe definir la instrumentación y forma de cálculo de cada métrica. En la literatura se han propuesto variadas métricas de calidad de agarre. En una revisión del tema se encontraron en la fase de agarre y síntesis de agarre hasta 24 métricas diferentes diseñadas para cuantificar la calidad del agarre (Rubert, León, *et al.*, 2017, León *et al.*, 2014, Rubert *et al.*, 2014, Falco *et al.*, 2018). Para la fase de validación, en este trabajo se adoptaron las siguientes métricas para agarres de poder y seguimiento de consignas: fuerza del dedo, fuerza de agarre, eficiencia del agarre, tiempo del ciclo de agarre, resistencia al deslizamiento, error de seguimiento y sobreimpulso definidas en Falco *et al.*, 2018, las cuales se definieron como métricas a implementar. Una vez seleccionadas las métricas, se deben describir las variables, el proceso para su cálculo y el entorno de medición de las métricas seleccionadas. En este trabajo, dicha descripción se hizo de la siguiente manera:

- *Fuerza del dedo (F_d).* Representa la fuerza máxima aplicada por cada dedo sobre el objeto, la cual se obtiene mediante el cierre de la mano y la toma de lectura de fuerza cuasiestática en las yemas de los dedos (se denomina *fuerza cuasiestática* a aquella con bajas oscilaciones, una vez realizado el agarre del objeto). En este trabajo se simuló la existencia de un sensor de fuerza en la yema de los dedos.

- *Fuerza de agarre (F_a).* Representa la fuerza máxima aplicada sobre el objeto, la cual se obtiene mediante el cierre de la mano y la toma de lectura de fuerza cuasiestática. En este trabajo se construyó un cilindro virtual a ser agarrado por la mano, simulando la existencia de una celda de carga en el interior del cilindro.

- *Eficiencia de agarre (E_a).* Representa el cociente entre la fuerza externa aplicada al objeto, de manera que produzca deslizamiento del objeto, y la fuerza aplicada al objeto con la mano. Se debe medir la fuerza externa en contacto con el objeto, y la fuerza realizada por la mano sobre el objeto, cuya lectura se toma en celda de carga.

- *Tiempo del ciclo de agarre (T_c).* Representa el tiempo requerido para que la mano haga los movimientos de cierre, agarre del objeto y apertura, el cual se calcula mediante la toma del tiempo desde el inicio de cierre de la mano hasta obtener una fuerza cuasiestática, una vez entrado en contacto con el objeto, cuyo valor se multiplica por dos; esto arroja el valor de T_c.

- *Resistencia al deslizamiento* (R_d). Representa la fuerza máxima soportada previo al deslizamiento del objeto. En este trabajo se obtuvo agarrando el cilindro con la mano, y aplicando una fuerza lateral tal que provoque el deslizamiento del objeto. Se mide la fuerza en la yema de los dedos en el instante del deslizamiento y se registra como R_d.

- *Error de seguimiento (E_r).* Representa el error medio cuadrático (RMSE) entre la fuerza de referencia y la fuerza aplicada al objeto.

- *Sobreimpulso (S_m).* Representa el valor pico máximo de la curva de respuesta en el seguimiento de la consigna de fuerza en las yemas de los dedos en la ejecución del agarre. Se promedia el valor obtenido en las yemas.

Estas métricas son implementadas en un entorno virtual, el cual incluye una mano robótica cuyos dedos se actúan con un mecanismo de Stephenson I de seis barras Norton y McCarthy, 2003, presentando un movimiento antropomórfico; un objeto cilíndrico para agarrar, y sensores de posición y fuerza para las estrategias de control.

Fase 2. Cálculo de métricas para las estrategias de control a evaluar

Se definen etiquetas para las técnicas de control a implementar describiendo las variables controladas, y el método de sintonización. Los resultados de las métricas adoptadas en la fase previa se organizan en una tabla de indicadores simples para cada técnica de control etiquetada. En el presente proyecto se seleccionaron aquellas técnicas viables de implementar en el entorno de simulación, las cuales se describen a continuación.

- *LQR con acción integral (C_1).* Permite control de posición (Fossen, 2011), cuya sintonización está basada en el modelo de la mano.

- *Control por modelo interno IMC (C_2).* Realiza un control de posición (Puerto *et al.,* 2011), cuya sintonización está basada en el modelo de la mano.

- *PID (C_3).* Implementa un control de posición (Kent y Engeberg, 2016), cuya sintonización está basada en el modelo de la mano (Chen y Seborg, 2002).

- *PI difuso (C_4).* Presenta un control de fuerza (Deng *et al.,* 2018), cuya sintonización está basada en el modelo de la mano (Castrillón Hernández *et al.,* 2015).

- *PI adaptativo (C_5).* Incorpora un control de fuerza (Deng *et al.,* 2016), cuya sintonización está basada en el modelo de la mano (Castrillón Hernández *et al.,* 2015).

- *Híbrido impedancia – PI (C_6).* Realiza un control de posición y fuerza (Fan *et al.,* 2018), cuya sintonización del lazo de fuerza es basada en el modelo (Castrillón Hernández *et al.,* 2015), y la sintonización del lazo de posición es basada en ensayo y error.

- *Híbrido IMC – PI adaptativo (C_7).* Utiliza un control de posición y fuerza, en cuyo lazo de posición se encuentra C_2, y en el lazo de fuerza C_5.

- *Híbrido LQR – PI difuso (C_8).* Aplica un control de posición y fuerza, en cuyo lazo de posición se encuentra C_1 y en el lazo de fuerza C_4.

Las técnicas de control de posición presentan la desventaja de tener picos altos de fuerza en el agarre, cuya fuerza puede causar daños en el objeto. Las estrategias híbridas presentan las ventajas combinadas del control de posición y fuerza, cuyo cambio de estado se ejecuta al alcanzarse un error de posición inferior al 10 %, cambiando de control de posición a fuerza. En técnicas de control posición, en el valor de desempeño de las métricas de error de seguimiento y sobreimpulso, es asignado un valor de nulo.

Fase 3. Cálculo del indicador compuesto

Un indicador se compone de un conjunto de datos que ayudan a medir objetivamente la evolución de un proceso (AENOR, 2003). Se distinguen dos tipos de indicadores: simples y compuestos. El primero se define como una función de una o más variables que conjuntamente miden una característica; y el compuesto (IC) se define como una combinación matemática de indicadores simples (Bas Cerda, 2014). En la literatura se encuentran metodologías para la construcción de indicadores, como el aporte en Bas Cerda, 2014 y (Nardo *et al.*, 2008), por tanto, se debe definir el procedimiento a seguir para la construcción del indicador compuesto. En el presente proyecto se adopta el método en Bas Cerda, 2014 basado en el trabajo de Nardo *et al.*, 2008, como guía para la propuesta del IC de desempeño. Los pasos utilizados para la construcción del IC en esta propuesta, aplicados al caso de estudio en este trabajo, son:

- *Marco conceptual.* El IC a construir tuvo como objetivo evaluar las técnicas de control en el desempeño del agarre de poder, dando a conocer cómo la selección de una estrategia específica incidía en el desempeño del agarre.

- *Selección de indicadores simples.* Se utilizaron los indicadores adoptados en la fase 1 del método, en este trabajo: F_d, F_a, E_a, T_c y R_d relacionadas con calidad del agarre, E_r y S_m, asociadas con el desempeño del algoritmo de control. Otras métricas fueron excluidas por su enfoque hacia agarres de precisión o a la calibración de instrumentación.

- *Población de datos.* Se seleccionó el grupo de estrategias de control que permitieran agarres de poder, y se realizaron los experimentos para el cálculo de los indicadores para cada técnica. En este trabajo las técnicas evaluadas se describieron en la fase 2 como: $C_1, C_2, C_3, C_4, C_5, C_6, C_7 y C_8$.

- *Normalización de datos.* Se implementó el método de normalización de reescalamiento, al presentar ventajas sobre otros métodos de normalización; como permitir la aplicación de datos cuantitativos, la conservación de las distancias relativas, el ajuste de los indicadores a la misma escala de medida y al mismo rango de variación (Bas Cerda, 2014).

- *Tratamiento de datos.* Se analizó la presencia de valores atípicos en los datos obtenidos en las diferentes métricas. En este trabajo no se encontró ninguno, consecuencia de la estrategia de prueba en un modelo virtual. Se hallaron datos estadísticos correspondientes a media, desviación estándar, curtosis y coeficiente de asimetría. De esta información, se concluyó que la métrica F presentaba una baja dispersión de datos, y una alta concentración alrededor de la media, según su valor de desviación estándar y curtosis, indicando un aporte bajo en información al IC.

- *Análisis multivariante.* Se halló la matriz de correlación entre los indicadores simples donde hubo una alta correlación entre F_d y F_a, lo que indicó la posibilidad de redundancia en la información aportada al IC. Luego se analizaron los componentes principales, donde se encontró que la proyección sobre dos componentes logró explicar el 72,45 % de la varianza. Esto se realizó mediante algoritmos para análisis de componentes principales en R, utilizando la interfaz gráfica *R commander* (Sáez Castillo, 2016). Analizando el plano de correlación en base a los dos componentes hallados, se observa la alta correlación entre las métricas F_d, S_m y F_a.

- *Ponderación y agregación de indicadores.* Se propuso un indicador, I_{C1} indicado en la ecuación (1). Se asignaron pesos iniciales de igual proporción. A partir de la información aportada por el tratamiento de datos y el análisis multivariante, los pesos en (1) se ajustaron teniendo en cuenta la correlación entre los indicadores F_a, F_d y S_m, asignándoles un peso bajo a dos de ellos. Ya que los indicadores F_d y R_d presentaron un alto valor de curtosis, indicando alta concentración de datos alrededor de la media, se le asignó a uno de ellos un peso levemente menor en comparación con la mayoría.

  Con la finalidad de comparar el indicador calculado con estos criterios, se implementó un algoritmo de optimización en la búsqueda de los pesos de los indicadores simples, de lo que se obtuvo un segundo indicador I_{C2}, mostrado en la ecuación (2). El proceso de optimización es un enfoque conocido como método de búsqueda simple de Nelder-Mead (Becker *et al.*, 2017), no requiere conocimiento de derivadas y tiende a producir resultados de convergencia eficientes. En la práctica, los pesos optimizados pueden dar lugar a pesos negativos, debido a la estructura de correlación ente indicadores simples. No se propone que los pesos optimizados se apliquen a ciegas, se plantean como una herramienta de aprendizaje para mostrar cuán lejos están los pesos de los valores óptimos, qué pesos de los indicadores tienen poco impacto en los resultados, e incluso que indicadores podrían eliminarse.

$$I_{C1} = 0,12\ F_d + 0,01\ F_a + 0,1975\ R_d + 0,1975\ T_c + 0,08\ E_a + 0,1975\ S_m + 0,1975\ E_r \quad (1)$$

$$I_{C2} = -0,372\ F_d + 0,1962\ F_a + 0,3381\ R_d - 0,0911\ T_c + 0,686\ E_a + 0,0961\ S_m + 0,1468\ E_r \quad (2)$$

- *Análisis de sensibilidad.* Se realizó con base al cálculo de las varianzas de los indicadores individuales y del indicador compuesto al aplicarlos a los datos; así, se definió *la sensibilidad* como el

cociente entre la varianza esperada de un indicador simple y la varianza total de salida. Este análisis dio a conocer la influencia de cada índice simple en el IC.

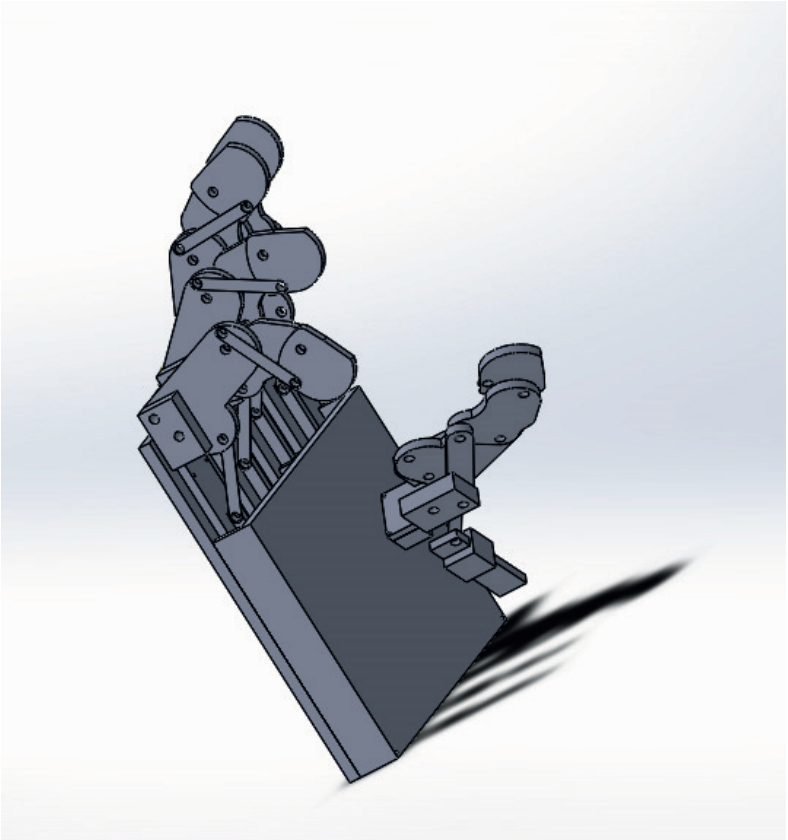

Figura 1. Modelo de mano virtual en SolidWords

Fuente: elaboración propia.

VALIDACIÓN EXPERIMENTAL DEL MÉTODO

El proceso para definición y validación del IC se llevó a cabo construyendo un prototipo virtual de una mano subactuada que utiliza mecanismos de barras, la cual se muestra en la figura **1**. En el ambiente virtual se puede realizar el control de posición y fuerza de los dedos. En las pruebas efectuadas para medir las métricas encontradas en la literatura (Rubert *et al.*, 2014, León *et al.*, 2014, Falco *et al.*, 2018, Rubert, León, *et al.*, 2017), solo fuerza de agarre, fuerza del dedo, tiempo del ciclo de agarre, eficiencia, resistencia al deslizamiento y seguimiento de fuerza, se pueden implementar en la mano virtual con que se cuenta, considerando agarres de poder. El prototipo virtual se construyó mediante los paquetes de software MSC Adams®, y MatLab® los cuales son comerciales y ampliamente utilizados por los científicos en el mundo. MSC Adams está diseñado para análisis

dinámico automático de sistemas multicuerpo (automatic dynamic analysis of multibody systems) y provee un gran conjunto de herramientas para construir ambientes virtuales compuestos de objetos 3D, además es compatible con software especializado de diseño asistido por computador (CAD), como SolidWorks. El motor de física de MSC Adams permite al usuario establecer propiedades como la gravedad, fuerzas y fuerzas generalizadas, 3D, pares, materiales de los cuerpos, entre otras. En MSC Adams también están disponibles una variedad de medidas físicas de variables y actuadores, lo que facilita el análisis comprensivo de un sistema mediante modelado simple y flexible de objetos sólidos. Esos objetos se interconectan mediante enlaces cinemáticos y restricciones de movimiento en una sola unidad, la cual corresponde a las características reales del sistema mecánico (Hroncová *et al.*, 2014). La herramienta MSC Adams Controls permite exportar el modelo dinámico calculado a MatLab. La propiedad de cosimulación implementada en MSC Adams facilita el intercambio de información entre los dos simuladores en tiempo de simulación, de modo que el usuario puede sacar ventaja de las capacidades sobresalientes de MatLab para análisis y diseño de controladores para el sistema robótico. Algunos trabajos reportados que utilizan MSC Adams y MatLab en cosimulación son Rubert, Kappler *et al.*, 2017, Rubert *et al.*, 2014 y Falco *et al.*, 2018, quienes demuestran el potencial de simulación para sistemas dinámicos mecánicos.

Se llevaron a cabo las pruebas para el indicador compuesto, en el entorno virtual mostrado en la figura **2**, ejecutando el agarre de un cilindro de diámetro pequeño, definido en la taxonomía propuesta en (Feix *et al.*, 2016) como un agarre de poder.

RESULTADOS

Siguiendo el método propuesto en este trabajo, se evaluaron estrategias de control realimentado en la funcionalidad de agarre de poder con una prótesis de mano, donde se calcularon los indicadores simples de fuerza del dedo, fuerza de agarre, resistencia al deslizamiento, tiempo de ciclo de agarre, eficiencia, sobreimpulso y error de seguimiento. Luego, se seleccionaron ocho estrategias de control a implementar. Después, se construyó un indicador compuesto, con base en la metodología descrita; por último, se evaluó el desempeño de los controladores. A continuación, se dan a conocer los resultados en la evaluación de los controladores mediante I_{C1} e I_{C2}.

En la figura **3** se ilustran los valores de desempeño que se obtuvieron con cada uno de los controladores evaluados según I_{C1} e I_{C2}, donde I_{C1} representa el indicador propuesto en base al método propuesto, e I_{C2} representa el indicador obtenido mediante un algoritmo de optimización con base al análisis de sensibilidad. A modo de validación comparativa del indicador I_{C1} frente a I_{C2}, se observa un alto grado de similitud en los valores de desempeño arrojados en controladores como C_3, C_4, C_5, C_6, C_7 y C_8 demostrando la congruencia del método propuesto para la construcción del indicador compuesto.

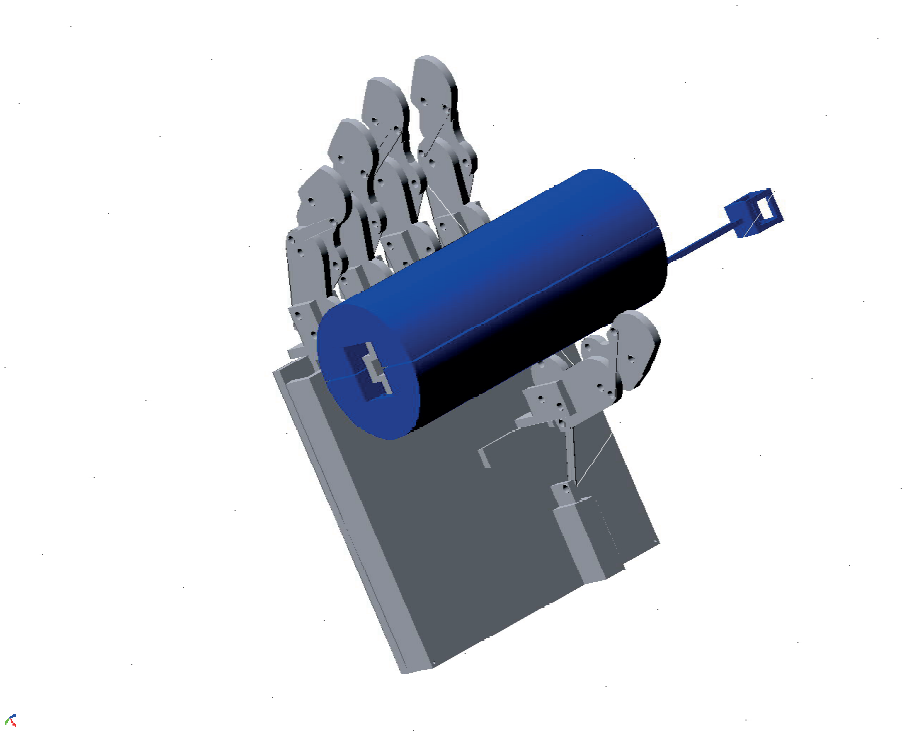

Figura 2. Entorno virtual en *MSC Adams*

Fuente: elaboración propia.

En el desempeño de los controladores se aprecia el mayor valor en C_7 y C_8 en ambos indicadores, y con menor desempeño los controladores C_1 y C_3. Con los valores de desempeño un diseñador podría elegir entre C_7 y C_8, dado que poseen un desempeño similar, aunque con requerimientos de implementación diferentes, con lo cual no se pierde funcionalidad en el agarre y se acopla a las necesidades y recursos del diseñador.

A continuación, se muestran algunos datos que permiten comprender el porqué del valor de desempeño de los controladores C_1, C_2, C_7 y C_8; y que a su vez muestran que los dos indicadores compuestos efectivamente coinciden en el desempeño que se desea evaluar.

En la tabla **I** se muestran los valores normalizados obtenidos con cada métrica por los controladores evaluados, se observa cómo aquellos con mayor desempeño (C_7 y C_8) presentan una mayor valoración de métricas simples sobre controladores con bajo desempeño (C_1 y C_3) según los IC, en métricas como F_d, F_a, R_d, T_c, S_m y E_r. Con ello se resalta la superioridad del control híbrido sobre el control de fuerza y posición, teniendo en cuenta las técnicas de control y métodos de sintonización implementados.

Es de aclarar en la presente investigación que el desempeño de un controlador en comparación con otros, en base a las métricas, no es indicativo de superioridad de una técnica de control respecto a otra, puesto que influyen aspectos como la calidad de sintonización, o el uso o no de modelos

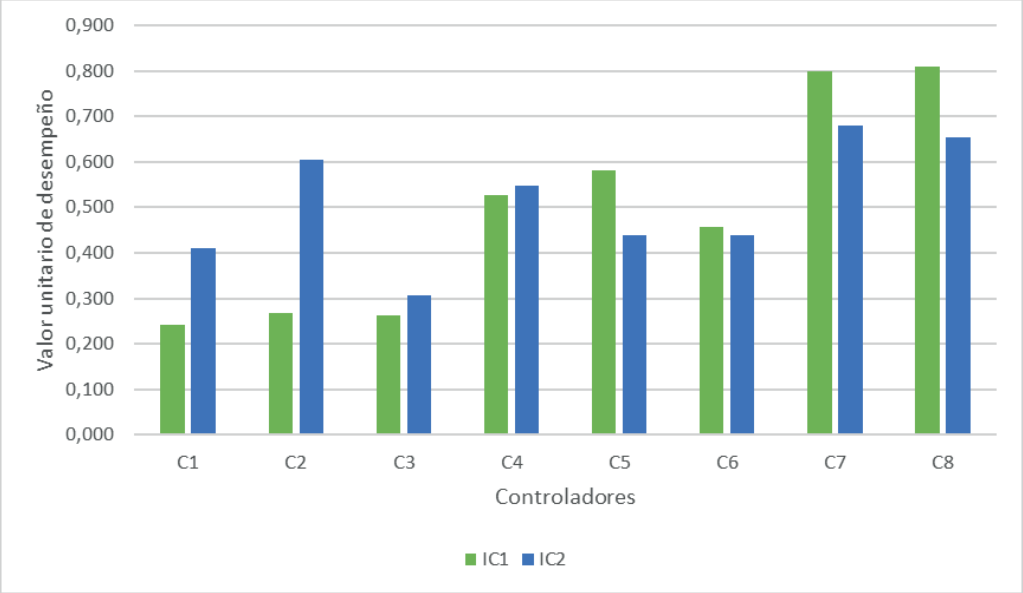

Figura 3. Indicadores compuestos

Fuente: elaboración propia.

Tabla I. Valores normalizados de los controladores en cada métrica

	C_1	C_3	C_7	C_8
F_d	0,395	0	1	1
F_a	0,511	0,014	1	1
R_d	0,667	0,333	0,8	0,733
T_c	0,734	0	0,867	0,745
E_a	0,012	1	0,280	0,427
S_m	0	0	0,987	0,997
E_r	0	0	0,975	0,985

En los valores normalizados, 1 indica un logro ideal del indicador considerándose el mejor, y 0 indica un logro nulo considerándose el peor.

Fuente: elaboración propia.

para el objeto o para la mano. Por tal razón, la actual propuesta de un método de comparación de desempeño de las técnicas centrado en el desempeño del agarre ofrece una herramienta analítica para decidir acerca de qué estrategia de control es más adecuada para una tarea específica con la prótesis, instrumentación y *hardware* disponible.

CONCLUSIONES

Cuando se desea comparar el desempeño de técnicas de control para el agarre de objetos, las decisiones se toman usualmente con base en criterios relacionados con el error de seguimiento de consignas y esfuerzos de control. De otro lado, las métricas de desempeño para evaluar la calidad de agarre evalúan aspectos disimiles en el agarre de poder, aunque de forma aislada. En este trabajo se ha propuesto un método tendiente a facilitar la toma de decisiones del diseñador en cuanto a la técnica de control más adecuada, entre varias disponibles, para el logro del agarre de poder con una prótesis específica. El método busca construir un indicador compuesto que agrupa variadas métricas para evaluar funcionalidad particular de agarre, y también para cuantificar el logro de seguimiento de consignas, facilitando la toma de decisiones acerca de la incidencia de la técnica de control en el logro del objetivo final.

En este trabajo se siguieron dos enfoques distintos para la construcción de un indicador compuesto, llegando a conclusiones similares con los dos indicadores, lo que muestra que, si el procesamiento de la información disponible es adecuado, el método propuesto lleva a conclusiones coherentes.

Este método podría utilizarse para evaluar otros aspectos como el diseño mecánico de la mano, el uso de ciertos actuadores o sensores, cuyo beneficio final no son del todo claros para que el diseñador de prótesis tome decisiones acertadas.

Trabajos futuros buscan evaluar el método propuesto en prototipos de laboratorio de prótesis de mano robóticas físicas.

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ESTUDIO DE CASO

Caracterización de la velocidad de caminata. Caso de estudio puente peatonal

Walking speed characterization. Case study pedestrian bridge

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Resumen

Contexto: La variable macroscópica más importante del flujo peatonal es la velocidad de caminata, ya que permite analizar el comportamiento y las condiciones en que está operando una infraestructura. En el presente estudio se determinó si existe una diferencia estadísticamente significativa entre velocidades medias temporales para tres tipos de infraestructuras y dos tipologías de usuarios.

Metodología: Se tomaron los tiempos que duraba un peatón en recorrer una distancia preestablecida en cada una de las tres infraestructuras contempladas: escaleras y plataforma de un puente peatonal, y una acera con pendiente del 0 %, localizadas en la ciudad de Tunja, Colombia, clasificando a los usuarios según sexo y sentido de circulación.

Resultados: La velocidad media temporal en las escaleras, para las mujeres, es de 0,81 m/s en ascenso y de 0,72 m/s en descenso. En cuanto a los hombres, la velocidad media temporal fue de 0,81 m/s en los dos sentidos de circulación. En relación con la plataforma y la acera, se obtuvo que la velocidad media temporal de las mujeres es inferior a la de los hombres.

Conclusiones: En el sentido de circulación ascenso se determinó que no hay una diferencia estadísticamente significativa, caso contrario a lo establecido para el sentido de circulación en descenso. Confrontando la velocidad media temporal determinada para las dos secciones del puente peatonal, con la velocidad media temporal de la acera, se estableció que hay una diferencia estadísticamente significativa, razón por la cual, es necesario caracterizar los comportamientos por separado en cada sección al momento de diseñar o de intervenir una infraestructura peatonal.

Palabras clave: caminar, peatón, puente peatonal, velocidad.

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Abstract

Context: The most important macroscopic variable of pedestrian flow is walking speed, this analyzes the behavior and operating conditions of a facilitie. In the present study, we established whether there is a statistically significant difference between temporary mean speeds for three types of infrastructures and two types of users.
Methodology: We measure the time it takes a pedestrian to travel a pre-established distance in each of the 3 contemplated facilities: stairs, platform of a pedestrian bridge and a sidewalk on a level grade located in the city of Tunja, Colombia, we classify to users according to gender and direction of circulation.
Results: The mean temporal velocity on the stairs, for women, is 0.81 m/s upward and 0.72 m/s downward. As for men, the mean temporal velocity was 0.81 m/s in both directions of circulation. In relation to the platform and the sidewalk, we find that the temporal average speed of women is lower than that of men.
Conclusions: In the upward movement direction, we find that there is no statistically significant difference between men and women, otherwise, to what is established for the downward movement direction. Comparing the temporal average speed determined for the two sections of the pedestrian bridge, with the temporary average speed of the sidewalk, we find that there is a statistically significant difference, which is why it is necessary to characterize the behaviors separately in each section at the time of designing. or do work at a pedestrian facility.

Keywords: walking, pedestrian, footbridge, walking speed.

Tabla de Contenidos

INTRODUCCIÓN

Con el crecimiento demográfico, aumenta la demanda de los sistemas de transporte para satisfacer la necesidad de movilidad de los habitantes, ya que, "a mayor población, mayor vivienda y mayor movilidad" (Serafín González, 2019, p. 36). El uso de los sistemas de transporte depende, en gran medida, del nivel de ingreso del grupo familiar; la tendencia es que personas con bajos ingresos hagan más uso de medios de transporte como el peatonal, el público y la bicicleta, mientras que las personas con ingresos más altos, "suelen desempeñarse como motoristas o pasajeros de automóviles" (Alcántara, 2010, citado por (Duarte *et al.*, 2018, p. 65). Todas las personas, en algún momento del día, se convierten en peatones, ya sea para ir a un parqueadero, a un biciparqueadero, a una parada de buses, acceder a espacios públicos o para realizar diferentes actividades.

Con el paso del tiempo, se han construido nuevas vialidades destinadas a mejorar la movilidad de los sistemas privados de transporte, disminuyendo, entre otros aspectos, la motivación, la percepción de seguridad y el nivel de servicio de las personas que realizan sus desplazamientos en modos de transporte amigables con el medio ambiente, como lo es el caminar. También, el aumento de vehículos motorizados ha generado, en varias ciudades de Latinoamérica, "grandes externalidades como: accidentalidad, mortalidad, morbilidad, congestionamiento vial, pérdida de horas efectivas, ruido y emisiones atmosféricas de contaminantes que afectan las características del aire y, en consecuencia, la salud de las personas" (Quevedo García *et al.*, 2017, p. 141). En la actualidad, y como se señala en la publicación Movilidad urbana y espacio público, "el caminar y el espacio público se han convertido en las principales categorías de análisis para repensar los esquemas de movilidad y ofrecer a las aglomeraciones un nuevo aire de vitalidad" (Serrano Romero, 2018, p. 17), por lo cual, se hace indispensable seguir investigando sobre las características que intervienen en la movilidad peatonal, ya sea detallando su comportamiento individual o sus características operativas.

Una variable que permite conocer directamente las características de operación en una infraestructura peatonal en un momento dado es la velocidad peatonal o de caminata, la cual es la relación entre la distancia recorrida por un peatón y el tiempo que tarda en recorrer dicha distancia, y esta, puede ser expresada en m/s, m/min y/o km/h. Guío Burgos (2009) indica que "la velocidad de caminata es la variable más importante en la modelación de los flujos peatonales" (p. 42), además, esta variable está condicionada por algunos factores externos como el clima, la topografía, el tipo de zona, las precipitaciones, el tipo de infraestructura peatonal, entre otros. Sanz Alduán (2016) señala que las condiciones del entorno físico y social, como la seguridad, comodidad y atractivo de la zona, determinan las velocidades al caminar, ya que son elementos que estimulan o impiden las velocidades deseadas por los individuos. Bañón Blázquez y Beviá García (2000) establecen que cada peatón circula siguiendo una pauta diferente, regulando a voluntad la velocidad a la que circula. Adicionalmente, Meister (2007) menciona que las velocidades de caminata también dependen de la actividad que las personas van a realizar. También, la velocidad es una de las tres variables macroscópicas jun-

to al volumen o tasa de flujo y a la densidad. Estas variables macroscópicas se relacionan entre sí, siendo la relación velocidad/densidad la más importante, ya que, a partir de esta, se pueden establecer algunas características como la "capacidad teórica, la velocidad a flujo libre y la densidad de congestionamiento en una infraestructura peatonal o vehicular, las cuales, son la base para el dimensionamiento e intervención de infraestructuras" (Villamarín Monroy (2018), p. 88). Guio Burgos y Poveda (2012) mencionan que "cuando el volumen peatonal es bajo, el espacio disponible para cada peatón permite que se desarrollen velocidades altas a flujo libre, pero a medida que va aumentando el volumen de peatones, disminuye la velocidad de caminata" (p. 144).

Una de las infraestructuras más cuestionadas son los puentes peatonales, debido, principalmente, a la falta de accesibilidad para una parte de la población que presenta algunas restricciones en su movilidad; sin embargo, este tipo de infraestructuras son, en algunos escenarios, la única alternativa que sirve para conectar dos puntos de manera segura. Hidalgo-Solórzano *et al.,* (2010), en su investigación "Motivos de uso y no uso de puentes peatonales en la Ciudad de México: la perspectiva de los peatones", señalan que los motivos por los cuales los usuarios hacen uso de los puentes peatonales son por seguridad y porque no hay otra forma de cruzar. Villamarín Monroy (2018) señala que algunas guías de diseño y planeación presentan como virtudes de los pasos peatonales a desnivel, reducir los problemas generados por la operación de los sistemas peatonales y vehiculares en una misma zona (Waka Kotahi NZ Transport Agency. 2009). Las infraestructuras peatonales a desnivel son construidas en situaciones urbanas donde el cruce peatonal a nivel puede causar accidentalidad o congestión (Banerjee *et al.,* 2018). El manual de señalización vial define a los puentes peatonales como una "estructura elevada sobre el nivel de la calzada que posibilita pasar de un lado al otro de la vía" (Ministerio de Transporte, 2015, p. 678); sin embargo, este tipo de infraestructuras también sirven de acceso a sistemas masivos de transporte como el sistema BRT (bus rapid transit, "bus rápido de transporte público") de la ciudad de Bogotá, Transmilenio.

Varias investigaciones se han centrado en este último aspecto, en analizar las características operativas en los accesos peatonales de los sistemas masivos de transporte, en especial, lo relacionado con la velocidad caminata. Una de las investigaciones más conocidas en el área peatonal fue realizada por John J. Fruin en 1971, quien, para estudiar la velocidad de caminata, tomó como referencia dos escaleras; una con inclinación de 32° y otra de 27°, situadas en una estación del tren de la ciudad de Nueva York, donde clasificó a los usuarios por edades, sexo y sentido de circulación (ascenso y descenso). Fruin obtuvo como resultado que la velocidad promedio, para la escalera de 32° de inclinación, es de 0,51 m/s en ascenso, mientras que, en descenso, la velocidad promedio es de 0,67 m/s. En relación con la velocidad promedio de ascenso y descenso en la escalera con inclinación de 27°, fue de 0,57 m/s y 0,77 m/s, respectivamente. En la tabla **I** se observan los datos registrados por Fruin en la escalera cuya inclinación era de 27°; mientras que en la tabla **II** se presentan los resultados de Fruin en la escalera cuya inclinación era de 32°.

En una estación del metro de Hyderabad (India), la velocidad promedio de caminata en escaleras, caso hombres, fue de 0,76 m/s, mientras que, para las mujeres, fue de 0,59 m/s. En promedio, y sin

Tabla I. Velocidades de caminata para la escalera de 27°

Escalera con inclinación de 27°						
Genero	**Hombres**			**Mujeres**		
Edad (años)	<29 años	30-50	50 <	<29 años	30 - 50	50 <
Ascenso	0,61	0,59	0,41	0,56	0,54	0,45
Descenso	0,93	0,81	0,60	0,67	0,65	0,56

Fuente: tomado de Fruin, 1971.

Tabla II. Velocidades de caminata determinadas por Fruin para la escalera de 32°

Escalera con inclinación de 32°						
Genero	**Hombres**			**Mujeres**		
Edad (años)	<29 años	30 - 50	50 <	<29 años	30 - 50	50 <
Ascenso	0,56	0,51	0,43	0,54	0,48	0,39
Descenso	0,83	0,69	0,57	0,59	0,51	0,47

Fuente: tomado de Fruin, 1971.

realizar ninguna clasificación, la velocidad media de caminata fue de 0,70 m/s (Patra *et al.*, 2017). En esta misma investigación señalan que, confrontando la velocidad entre hombres y mujeres, los hombres caminan un 30 % más rápido con respecto a la trayectoria en ascenso y un 27 % más rápido con respecto a la trayectoria en descenso. En una estación del metro de Hong Kong determinaron que la velocidad de ascenso y descenso es de 0,8 m/s y de 0,93 m/s en ascenso y descenso, respectivamente, mientras que para una estación del metro de Londres, la velocidad de ascenso determinada fue de 0,58 m/s y en descenso de 0,67 m/s (Banerjee *et al.*, 2018). Las velocidades a flujo libre en escaleras, en general, oscilan entre 0,45 m/s y 0,9 m/s para una trayectoria en ascenso, y entre 0,57 m/s y 1,08 m/s para una trayectoria en descenso (Banerjee *et al.*, 2018).

En cuanto a las velocidades en secciones uniformes, como las aceras, la velocidad de caminata establecida por el *Highway Capacity Manual* es de 1,2 m/s (Transportation Research Board, 2010). Esta velocidad ha sido tomada en varias investigaciones como un referente en el diseño de infraestructuras peatonales.

El objetivo principal de esta investigación es calcular la velocidad media temporal de caminata en dos secciones de un puente peatonal, escalera y plataforma, para dos tipologías de usuario, los cuales están clasificados según su sexo y sentido de circulación. Adicionalmente, se concluirá cuáles

son las diferencias de las velocidades media temporales calculadas entre cada parte del puente peatonal que se seleccionó para realizar el estudio y determinar si existe una diferencia estadísticamente significativa. Por último, se confrontarán las velocidades determinadas para cada parte del puente peatonal seleccionado con una muestra de velocidades determinadas en una acera peatonal que tiene una pendiente del 0 %, y conocer si hay una diferencia estadísticamente significativa

Al ser la velocidad una variable clave para estudiar el comportamiento y determinar algunos parámetros operacionales de una infraestructura, se espera que con esta investigación exista un referente teórico al momento de intervenir o construir una sección de un puente peatonal. Además, se espera que este estudio incentive a expertos en la materia para seguir profundizando y mejorando la operación en este tipo de infraestructura.

METODOLOGÍA

El puente peatonal seleccionado para el desarrollo de la presente investigación sirve de acceso a la sede de la Universidad Pedagógica y Tecnológica de Colombia (UPTC), el cual es uno de los lugares principales que genera y atrae viajes en la ciudad (Grupo de Investigación y Desarrollo en Planeación del Transporte, y Secretaría de Tránsito, 2012). Márquez (2015) señala que dicho puente peatonal es el más usado en la ciudad de Tunja. En el estudio realizado en convenio entre la UPTC y la Alcaldía Mayor de la ciudad de Tunja se determinó que el 42 % de los viajes se realizan a pie; el 33,7 %, en TPCU (transporte público colectivo urbano), y el 12 %, en vehículo particular; además, que los principales motivos por los cuales las personas realizan sus desplazamientos es por regreso a casa (45,5 %), trabajo (20,8 %) y estudio (18,8 %). Debido al uso del suelo que hay en el área aferente al puente peatonal, las velocidades determinadas para el sentido de circulación ascenso obedecen a viajes cuyo propósito es de estudio o trabajo, mientras que las velocidades determinadas para el sentido de circulación en descenso obedecen a viajes con motivo regreso a casa, principalmente.

En cuanto a las características físicas del puente estudio, la distancia total de la escalera del costado oriental es de 16,57 m, siendo el ancho de la sección de 1,47 m (22 escalones). Con respecto a la plataforma, se consideró un ancho de 1,70 m y una distancia base para medir el tiempo de 10,83 m, la cual obedece a la mitad de la longitud total de la plataforma. En la figura **1**, se presenta el puente peatonal estudio.

Para la toma de información se identificaron a los usuarios de acuerdo con las siguientes características: sexo (hombre o mujer) y el sentido de circulación (ascenso o descenso). Inicialmente, se establecieron unos puntos de referencia y la distancia que hay entre cada punto, se cronometró el tiempo que tardaba cada persona en recorrer la distancia, para luego promediar todos los tiempos y obtener una velocidad media temporal. Para un mejor estimativo de la velocidad de caminata, se realizó el seguimiento a la misma persona en las dos secciones del puente que fueron consideradas; cuando esta seleccionaba, terminaba su trayectoria, inmediatamente se seleccionaba a la siguiente

Figura 1. Puente peatonal estudio
Fuente: elaboración propia.

persona que haría uso de la infraestructura peatonal en la trayectoria que se estaba caracterizando. Este procedimiento se realizó inicialmente para las personas que seguían una trayectoria en ascenso y luego para las personas que descendían. El periodo de la toma de información se hizo entre las 10:35 horas y las 14:35 horas en un día hábil (jueves), de manera que se pudiese caracterizar un flujo bidireccional debido que se relaciona con el periodo pico del medio día en un día típico. Durante el periodo de estudio se contabilizaron 1588 personas, de las cuales, 595 corresponden a mujeres (37,5 %) y 531 a hombres (33,4 %) que seguían una trayectoria en ascenso. En relación con la trayectoria en descenso, se contabilizaron 265 mujeres (16,7 %) y 197 hombres (12,4 %). En la tabla **III** se puede observar el tamaño de la muestra referente a las velocidades calculadas según sexo y sentido de circulación.

Las velocidades determinadas en la plataforma del puente peatonal no se segregaron por sentido de circulación, obteniendo como tamaño muestral 432 y 402 registros de mujeres y hombres, respectivamente.

Tabla III. Tamaño muestral de velocidades en el puente peatonal

Hombre Ascenso	Hombre Descenso	Mujer Ascenso	Mujer Descenso	Total tamaño de la muestra
250	152	268	164	834

Fuente: elaboración propia.

Posteriormente, se compararon las velocidades calculadas para cada parte del puente que fue seleccionado para el desarrollo de la investigación con una muestra de velocidades calculadas para una sección transversal peatonal continua (acera peatonal) con una pendiente del 0 %, y, así, establecer si hay una diferencia estadísticamente significativa. Para el cálculo de las velocidades en la acera peatonal, se tomaron los tiempos que una persona duraba en recorrer una distancia predeterminada. En esta infraestructura se contabilizaron 66 tiempos de viaje para el caso de las mujeres, y 57 para hombres.

Resultados

A partir de las longitudes establecidas de la escalera y de la rampa se calcularon las velocidades según la tipología de usuario considerada para cada sección. Para una mejor interpretación de las velocidades de caminata determinadas, se plantearon dos hipótesis: una nula, donde se consideran que las velocidades medias son iguales, y una alterna, en la que las velocidades medias no son iguales.

Escaleras ascenso

En relación con esta parte del puente peatonal estudio-sentido de circulación ascenso, la velocidad media temporal de caminata de las mujeres determinada es de 0,806 m/s con una desviación estándar de 0,156 m/s. La velocidad media temporal calculada para los hombres es de 0,811 m/s, con una desviación estándar de 0,144 m/s. Para este caso, y con un nivel de confianza del 95 %, la hipótesis nula no puede rechazarse.

Escaleras descenso

Con respecto al sentido de circulación descenso, la velocidad media temporal de caminata de las mujeres calculada es de 0,721 m/s, con una desviación estándar de 0,151 m/s. Para los hombres, la velocidad media temporal determinada es de 0,806 m/s con una desviación estándar de 0,161 m/s. Para este escenario, la hipótesis nula se rechaza con un nivel de confianza del 95 %.

Escalera mujeres - ascenso vs. descenso

Si se confronta la velocidad media temporal de caminata de las mujeres que ascienden (0,806 m/s), con la velocidad media temporal de las mujeres que descienden (0,721 m/s), se determina que, para un nivel de confianza del 95 %, puede rechazarse la hipótesis nula.

Escalera hombres - ascenso vs. descenso

Al ser la velocidad media temporal de los hombres que ascienden 0,811 m/s, y de 0,806 m/s, la velocidad media temporal de los hombres que descienden, para un nivel de confianza del 95 %, no puede rechazarse la hipótesis nula.

Velocidad en la plataforma

Para la plataforma del puente estudio, se determinó que la velocidad media temporal de las mujeres es de 1,188 m/s, con una desviación estándar de 0,21 m/s, mientras que, para los hombres, la velocidad media temporal de caminata determinada es de 1,246 m/s con una desviación estándar de 0,21 m/s. Por lo anterior, y para un nivel de confianza del 95 %, se rechaza la hipótesis nula.

Resultados velocidad de caminata en una acera

La velocidad media temporal de caminata en la acera, para el caso de las mujeres, es de 1,267 m/s, con una desviación estándar de 0,226 m/s, mientras que, para los hombres, es de 1,392 m/s, con una desviación estándar de 0,195 m/s. En este caso, y para un nivel de confianza del 95 %, se rechaza la hipótesis nula.

Según Guío Burgos (2009), para caracterizar de mejor manera la variable velocidad, se determina la velocidad media espacial, la cual "se calcula dividiendo la distancia recorrida en el tiempo promedio que tardan las personas en recorrer esa distancia" (p. 36). Por lo anterior, y de acuerdo con los resultados que ya se describieron, se elaboró la tabla **IV** que detalla la velocidad media temporal y media espacial, según el sexo y la sección considerada. Adicionalmente, se presentan los percentiles 15 y 85, los cuales sirven de referencia al momento de intervenir y caracterizar una infraestructura peatonal.

Prueba de diferencia de velocidad media

Se utilizó la prueba de hipótesis mediante el cálculo del estadístico Z calculado de acuerdo con la ecuación (1):

$$Z_{calculado} = \frac{\bar{x}_1 - \bar{x}_0 + \epsilon}{\sqrt{\left(\frac{\sigma_0^2}{n_0}\right) + \left(\frac{\sigma_1^2}{n_1}\right)}} \quad (1)$$

Tabla IV. Velocidades de caminata en un puente peatonal

Sección	Sexo	Trayectoria	Velocidad media temporal (m/s)	Desviación estándar
Escalera	Mujer	Ascenso	0,806	0,156
		Descenso	0,721	0,151
	Hombre	Ascenso	0,811	0,144
		Descenso	0,806	0,161
	Mujer		0,774	0,159
	Hombre		0,809	0,150
Plataforma	Mujer	E - O	1,250	0,213
		O - E	1,088	0,182
	Hombre	E - O	1,295	0,206
		O - E	1,165	0,183
	Mujer		1,188	0,217
	Hombre		1,246	0,207
Pendiente de acera 0 %	Mujer		1,267	0,226
	Hombre		1,392	0,195

Fuente: elaboración propia.

Donde:
$\bar{x}_i$: velocidad media espacial en la condición i (para $i = 1$ o 0).
ϵ : error aleatorio.
σ_i: desviación estándar de los datos en la condición i.
n_i: tamaño de la muestra en la condición i.
Las comparaciones se realizaron para un nivel de confianza del 95 %, lo que permite utilizar un valor de $Z_{\text{teórico}} = 1,96$, los resultados se muestran en la tabla **V**.

Se observa, en la tabla **V**, y a excepción de los escenarios de ascenso-descenso hombre y ascenso hombres-mujeres, que las velocidades medias de caminata presentan una diferencia significativa. Se prevé que ese comportamiento se debe a una variable presente en el comportamiento de las personas en sus desplazamientos; dicha variable es el motivo del viaje. En las figuras **2** y **3** se observa la velocidad media en periodos de 15 minutos a lo largo del periodo de toma de información para escaleras y plataforma.

También en las figuras **2** y **3**, se observa que las velocidades varían de acuerdo con la hora, en especial en los horarios de salida de la jornada laboral o estudiantil de la mañana y al ingreso a las

Tabla V. Prueba de diferencia de velocidad de caminata

Entorno		Comparación	Z calculado	Decisión
Escalera	Mujer	Ascenso - Descenso	5,61	Diferencia significativa
	Hombre	Ascenso - Descenso	0,31	Iguales
	Ascenso	Mujer - Hombre	-0,38	Iguales
	Descenso	Mujer - Hombre	-4,83	Diferencia significativa
Plataforma	Mujer	Este a oeste - Oeste a este	8,41	Diferencia significativa
	Hombre	Este a oeste - Oeste a este	6,58	Diferencia significativa
	E - O	Mujer - Hombre	-2,44	Diferencia significativa
	O - E	Mujer - Hombre	-3,75	Diferencia significativa
		Mujer - Hombre	-3,95	Diferencia significativa
Acera	Hombre	Escalera - Plataforma	34,07	Diferencia significativa
	Mujer	Escalera - Plataforma	32,39	Diferencia significativa
	Hombre	Plataforma - Acera	-5,25	Diferencia significativa
	Mujer	Plataforma - Acera	-2,66	Diferencia significativa
		Mujer - Hombre	-3,29	Diferencia significativa

Fuente: elaboración propia.

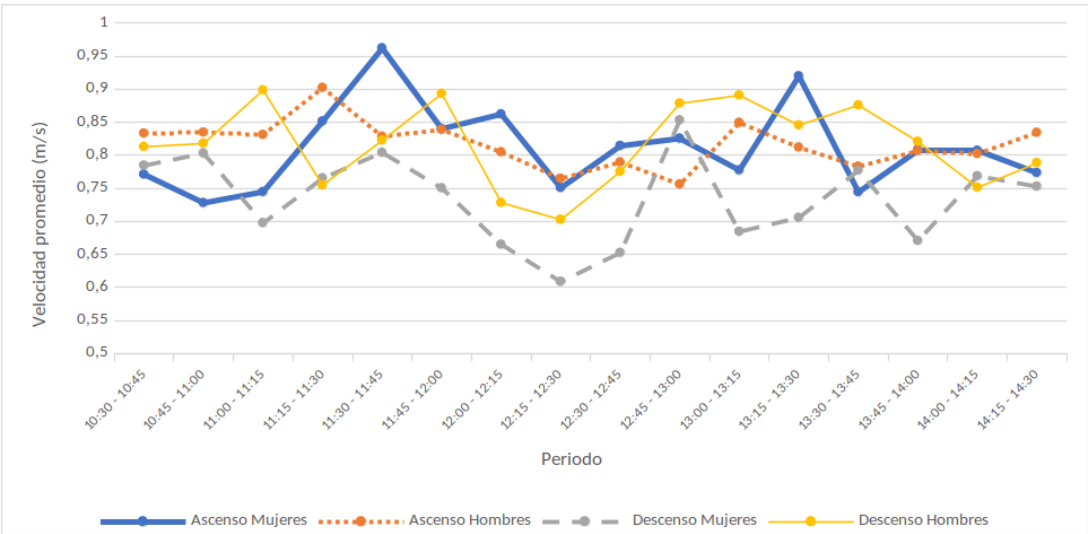

Figura 2. Velocidades medias de caminata en periodos de 15 minutos - Escalera

Fuente: elaboración propia.

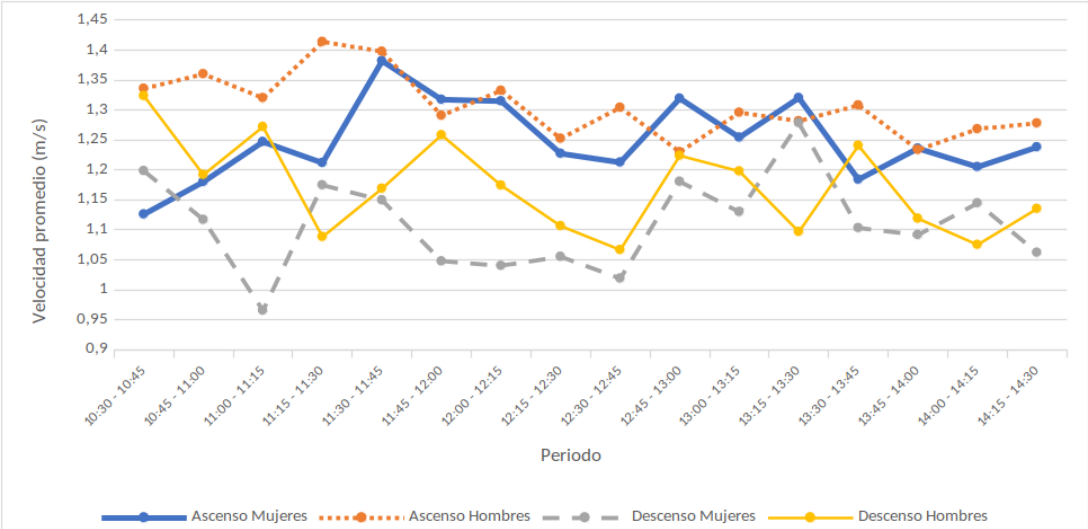

Figura 3. Velocidades medias de caminata en periodos de 15 minutos - Plataforma

Fuente: elaboración propia.

mismas actividades de la tarde. También, se observa que en el periodo comprendido entre las 12:30 horas y las 13:30 horas las velocidades medias disminuyen.

Para el caso estudio, y debido al uso del suelo de la zona aferente al puente peatonal, los principales motivos de viaje, para el caso del sentido de circulación ascenso (escaleras) y oeste-este (plataforma) son estudio y trabajo, mientras que el sentido de circulación descenso (escaleras) y este-oeste (plataforma) se debe a viajes con motivo regreso a casa.

CONCLUSIONES

La variable motivo de viaje se debe considerar al momento de caracterizar las velocidades medias de caminata, en especial cuando se desea conocer la capacidad y el nivel de servicio en que está funcionando una infraestructura peatonal.

Para el caso de las mujeres, la velocidad media temporal en la acera es un 36,39 % más alta en relación con la velocidad determinada en las escaleras-ascenso, un 43,10 % más alta con respecto a la velocidad de la escalera-sentido de circulación descenso, y un 6,2 % más alta que la velocidad media temporal establecida para la sección de la plataforma del puente peatonal.

La velocidad media temporal de los hombres, en la acera, es un 45,86 % más alta en relación con la velocidad determinada en las escaleras-sentido de circulación ascenso, un 46.25 % más alta con respecto a la velocidad de la escalera-sentido de circulación descenso, y un 11,52 % más alta que la velocidad media temporal establecida para la sección de la plataforma del puente peatonal.

En cuanto a la velocidad media temporal en ascenso, y teniendo en cuenta la distribución por sexo, se estableció que no hay una diferencia estadísticamente significativa, mientras que para el sentido de circulación en descenso hubo una diferencia estadísticamente significativa. En el escenario hombres y mujeres, y confrontando la velocidad media temporal en las escaleras sentido de circulación ascenso y descenso, con la velocidad media temporal en la plataforma por género, se encontró una diferencia estadísticamente significativa para los cuatro casos.

Confrontando la velocidad media temporal en la plataforma y en la acera, tanto de mujeres como de hombres, se determinó una diferencia estadísticamente significativa.

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ESTUDIO DE CASO

Learning Strategy for Programming Supported by Meaningful Learning, Brain-Based Learning, and Aesthetic Disposition

Estrategia de aprendizaje de la programación apoyado en aprendizaje significativo, *brain-based learning* y disposición estética

Omar Iván Trejos Buriticá [1], Luis Eduardo Muñoz Guerrero [2]

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Abstract

Objective: To analyze and establish if there is a relationship between the aesthetic distribution of elements on the board and its impact on the learning of computer programming.

Methodology: This study was conducted in parallel between two groups per semester from 2015 to 2018. The aesthetic elements referred to in this research were applied in one of the groups, and these elements were removed in the other one. The research is qualitative, with a final quantitative component.

Results: The results show a direct relationship between the learning of computer programming by students and the aesthetic disposition mentioned in this article.

Conclusions: It is concluded that knowledge is more understandable and meaningful for the student when it is aesthetically distributed with the resources of the classroom, which facilitates storing knowledge in the long-term memory.

Funding: Universidad Tecnológica de Pereira

Keywords: meaningful learning, teaching, master class, aesthetic skills, engineering, computer programming

Resumen

Objetivo: Analizar y establecer si existe relación entre la disposición estética de elementos en el tablero y su impacto en el aprendizaje de la programación de computadores.

Metodología: Este estudio se realizó en paralelo entre dos grupos por semestre del año 2015 al 2018. Los elementos estéticos referidos en esta investigación se aplicaron en un grupo, y dichos elementos fueron removidos en el otro. La investigación

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es de carácter cualitativo, con un componente final cuantitativo.
Resultados: Los resultados evidencian una relación directa entre el aprendizaje de la programación de computadores por parte de los estudiantes y la disposición estética a la que se refiere este artículo.
Conclusiones: Se concluye que el conocimiento es más comprensible y significativo para el estudiante cuando está estéticamente distribuido con los recursos del aula, lo cual facilita la ubicación del conocimiento en la memoria a largo plazo.
Financiamiento: Universidad Tecnológica de Pereira

Palabras clave: aprendizaje significativo, enseñanza, exposición magistral, habilidades estéticas, ingeniería, programación de computadores

Table of Contents

Introduction

In modern times, the language of technology has become the natural language of young people. This means that university teachers must develop competencies that allow them to tune in to this natural language (Ministerio de las TIC, 2012), which enable them to respond, within a more suitable framework, to modern realities and the uncertainties generated by the knowledge of their discipline. Such competencies should be included in their professional training, which also creates a better opportunity to rely on components that strengthen motivation (Ausubel, 1963).

Engineering teachers generally do not have the required pedagogical training to deliver their knowledge in such a way that learning objectives can be efficiently achieved. However, it is essential that the engineering teachers play two roles: that of the engineer, a title earned as a result of their knowledge in the discipline; and that of the teacher, since this is the springboard to share the knowledge of the discipline (Fríes *et al.*, 2014). Reaching the learning goals through more expeditious ways will only be possible if teachers assume their role from both sides and prepare for the articulation of knowledge in the training process, with strategies that allow the students to assimilate what is imparted in the classroom (Barriga-Arceo & Hernández-Rojas, 2002).). This paper proposes a strategy

that allows, through a very simple process, the knowledge acquired by the students to be recorded in their short and long-term memory if teachers make use of the strategy as it is recommended herein, attempting to fulfill the learning objectives in an easy, understandable, and communicative way, so that the students can represent their own knowledge.

This strategy has been used at a research level in the Systems and Computer Programming program of Universidad Tecnológica de Pereira during the 1^{st} and 2^{nd} semesters of the years 2015, 2016, 2017, and 2018. Efforts have been made to be rigorous in the application of this strategy, informing the students about the process, its features, and the procedures used for assessing knowledge, as well as the qualitative and quantitative measuring tools that provide feedback throughout the experience. Both groups immersed in the research correspond to different subjects, which aims for objectivity in the analysis of results.

It is worth noting that it is not possible to design and apply a unique and perfect way to carry out a session or give a lecture, which depends on diverse factors associated with teacher-student interaction in the classroom. However, it is possible to contribute elements of judgment for the teacher to use tools that may strengthen diverse classroom strategies, including master classes (Herrán, 2009), which continues to be, as an interaction space, one of the most direct and applicable methods, without neglecting the communicative advantages of information and communication technologies (ICTs) in this context (Onrubia, 2005).

This article proposes a way to take advantage of the benefits of master class presentations by means of aesthetic skills, whose incorporation, as evidenced by the results, strengthens this learning strategy in such a way that it enables the short and long-term retention of knowledge.

Under these premises, the following research question arises: Is the incorporation of aesthetic elements on the board a determining factor in enabling a more efficient way to reach the a student's learning goals? It should be noted that some of the reflections presented here are recommendable and suggestible in direct master classes or those supported by video streaming.

This paper is one of the products of the unfunded research project "Development of a methodological model for learning imperative programming in Systems Engineering based on Meaningful Learning, Learning through Discovery, and the 4Q model of thinking preferences" [*Desarrollo de un modelo metodológico para el aprendizaje de la programación imperativa en Ingeniería de Sistemas basado en Aprendizaje Significativo, Aprendizaje por Descubrimiento y el Modelo 4Q de preferencias de pensamiento*], which was approved by the Vice-Principalship of Research, Extension, and Innovation of Universidad Tecnológica de Pereira.

THEORETICAL FRAMEWORK

The word 'strategy' is currently used in a broad and versatile way, even though, in all its possible meanings, it implies an organized and systematic set of procedures used to achieve specific

objectives accepted by a given community. It can be described qualitatively and quantitatively, and it is generally circumscribed in the world of science (Lerma-González, 2014). Alongside this word, 'methodology' implies a set of methods which have been validated, accepted, and verified for the accomplishment of particular objectives within the framework of scientific research. A simple procedure, in spite of itself, cannot be considered as a methodology (Cortés & Iglesias, 2004); it could be considered as a strategy.

In the operational domain, a strategy implies processes of information gathering, data analysis, data filtering, and validation, as well as the ordering process for later analysis, so that achieving scientific conclusions is made possible, along with eventually approaching nature, the laws that govern it, and the ways it interacts with society and individual human beings (Hernández-Sampieri *et al.*, 2006). Methodologies are based on postulates and theories that constitute their base or foundation and seek to broaden the horizons and approach the frontiers of human knowledge (Sabino, 2002). A strategy is, in simple terms, a tool used by a methodology to validate its effectiveness.

Master classes are one of the strategies that teachers can use to share disciplinary knowledge with their students, aided by a desirable systematic organization that leads to the achievement of scientific learning objectives (**?**). Although, as a general rule, master classes happen in a classroom, this is not totally true today, since virtual resources as well as modern telematic and open interactive spaces with students enable the implementation of master classes in similar (and sometimes better) conditions to those supplied in traditional face-to-face environments (Sáez-López *et al.*, 2010).

The master class (or master exposition) has been the space where the interaction between teachers and students can take place in a more direct way, since communication happens in human natural conditions, without technological mediation. Here, it is possible to perceive all the other elements that are part of human dialog, which correspond to forms of communication that, being visible, are not audible, but nevertheless strengthen the process (Trejos-Buriticá, 2013).

Training programs in engineering seek to make available to students (future engineers) the necessary tools that, based on the resources provided by the basic sciences, allow them to assimilate, model, intervene, optimize, improve, give feedback on, and modify the outside conditions under which human beings live, either natural or artificial (Blanchard, 2000). Systems engineering seeks support from new technological tools, modern advances, and electronic computational technology, in order to make said tools more optimal in their use and appropriation.

The teachers of engineering programs have been trained as engineers but not as teachers, and even though many of them have refined their teaching and learning strategies, it is worthwhile to keep in mind that their training profile is not pedagogical but engineering- centered, and this leads to the consideration that it is convenient to deepen not only their disciplinary knowledge, but also the theories, strategies, and activities that strengthen their teaching skills for the benefit of their students.

A reflection stems from the previous consideration, concerning the question of whether they are engineers-teachers, teachers-engineers, or simply both, since they carry out both tasks. The knowledge, assimilation, appropriation, application, and evaluation of learning theories, teaching strategies,

and mechanisms, as well as the modes and means of direct, indirect, synchronous, asynchronous, mediated, and non-mediated communication, are part of the reflections and practices that, in these modern times, are part of the duties of engineers, regardless of their profile, with respect to their teaching activities. To put it in other words, their teaching apostleship must be steered in the right direction, where learning, as a primary objective, justifies the presence of students in the academic scene.

These are the times when the teaching environment invites to reflect on the fact that society's constant changes and evolution, with respect to the use of technologies in general and the educational world in particular, have reinforced the perception that ICTs are necessary in basic or professional training processes (Sáez-López *et al.*, 2010). According to the standards established by the United Nations Organization for Education, Science, and Culture, it is understood that the so-called ICTs can help students get the necessary skills to become a) competent in the use of information technologies; b) searchers, analyzers, and evaluators of information; c) problem solvers and decision makers; d) creative and successful users of productivity tools; e) communicators, collaborators, publishers, and producers; and f) informed and responsible citizens capable of contributing to society (UNESCO, 2008).

There is something behind all this that, if not explicit, is there as part of the reflections. The appropriate use of ICTs forces teachers to develop certain skills which might not be present in the personal field, especially when they are digital immigrants, but it should be in the media orbit as a product of their use and interaction: the need to rely on some aesthetic considerations, skills that stand out as the corpus of this research. How does this happen? A very simple way to demonstrate this is the interactive communication that takes place through the Whatsapp service, so popular in these times.

Since communication through this app is electronic, the type of standard font used (arial or times new roman) corresponds to an absolutely legible and understandable type. Even if we were using expressive emoticons in this context, communication would be much more understandable, in comparison with the type of handwriting used by a teacher or a student. This suggests that teachers' histrionic skills, their communicative ability, knowledge, and disciplinary adequacy are not enough; it is also essential to rely on other skills to support the teaching practice.

METHODOLOGY

The strategy presented in this paper has been used in the Programming I and Programming II courses of the Systems and Computers Engineering program at Universidad Tecnológica de Pereira, during the first and second semesters of 2015, 2016, 2017, and 2018. It should be kept in mind that the content of these courses is organized by topics, and that each topic is associated with a week; four topics have been chosen as a base for experimentation and research. In the Programming I course, the content deals with functional programming and its implementation through the Scheme langua-

ge. The content of the Programming II course content corresponds to the paradigm of imperative programming and its implementation using DevC++, which corresponds to the C++ language environment in its purely imperative aspects.

Each week has three sessions, which are dedicated to each topic for its exposition, revision, appropriation, and application. The first session of each week is devoted to theoretical explanation, definition of applications, and analysis of examples. The second week is focused on reinforcing theory, reviewing applications, and analyzing further examples, one of which was completely solved by the teacher, including the corresponding IDE (Integrated Development Environment), depending on the course. The other exercises are solved by the students. In the third session, there is a quick review of the studied theory, and, for the application part, exercises are formulated as a workshop for them to be solved in the computer room with teacher accompaniment.

The two different groups of courses were developed in parallel with the purpose of making the corresponding comparative analysis, without one course affecting the development of the other. In each of them, the master class strategy had a different connotation.

With one of the groups, the master class was characterized by an intentional aesthetic use of the board, with an appropriate use of handwriting and a geometrical distribution intended to make the most of the board space, as well as a utilization of the useful area of the board based on the sequential distribution of the written text (left to right and up to down).

The drawings, diagrams, representations, and outlines were clear and artistic enough. The diagrams associated with the Cartesian plane were made with tools such as a didactic compass, a scaled rule, and a square, so that they were as meaningful as possible.

With the other group, the exposition was the opposite (intentionally), that is, good handwriting was totally absent, including some unintelligible annotations, a totally random and messy distribution and use of the board space, a complete absence of sequential order in the notes, an intentionally diffused graphic representation, lack of reference of some graphics on the Cartesian plane, and a lack of use of didactic tools that could make a clear geometry possible.

During and at the end of the master classes, the students were invited to copy in their notebooks the information presented on the board by the teacher exactly as it was written. For each of the groups in parallel, Whatsapp groups were allowed to be created separately, so that the students could expose their concerns. These groups included the teacher.

All the questions asked through the Whatsapp groups were answered, and this made it possible to monitor the questions. The midterm written evaluations were carried out in two groups in similar conditions, in close dates (normally, the difference was not greater than two days) and with very similar formulations, exercises, and approaches, so that it was possible to conduct a result that was as objective as possible, from the perspective of its approach, and keeping distance from the respective conceptual boundaries of each programming paradigm.

RESULTS

For the purpose of this analysis, the groups where the strategy described in the Methodology section was applied will be called 'Groups with Aesthetic' (G with A). In a similar way, the groups where this strategy was completely absent will be called 'Groups without Aesthetic' (G without A). Table 1 shows a summary of the students who made up the groups participating in this study.

Table 1. Students involved in the study

Year	Sem	Students		Tot
		G with A	G without A	
2015	I	22	21	43
	II	23	22	45
2016	I	23	23	46
	II	20	20	40
2017	I	19	18	37
	II	21	20	41
2018	I	21	21	42
	II	20	20	40
Total		**169**	**165**	**334**

Source: Authors.

Tables 2a and 2b show a summary of the queries carried out in person and via Whatsapp (including text, audio, video, and pictures) during the semester. To facilitate data treatment, the students' partial grades have been averaged. The specific details of each group are available for later verification.

It is worth noting that a query through Whatsapp is defined as any interaction that could be framed within one of the four categories (text, audio, picture, video).

Table 3 shows the comparative results of the quantitative valuations of the average of the midterm and final examinations for each group.

During the last week of each semester, the students were asked to anonymously write their opinions about the experience in a free and spontaneous way, focusing on those factors that they considered to be of higher importance for the development of the course, which had affected the learning process in a significant way.

Table 2a. Queries made – Groups with Aesthetic

Year	**Sem**	**In-Pers. Q.***	**Q. via Whatsapp**				**Avg**
			Txt	**Audio**	**Pict**	**Video**	
2015	I	189	19	9	5	2	224
	II	267	23	8	3	3	304
2016	I	354	27	9	3	2	395
	II	312	38	9	4	2	365
2017	I	265	36	7	3	3	314
	II	233	32	7	4	3	279
2018	I	423	42	9	5	3	482
	II	255	23	10	4	4	296
Total		**2298**	**240**	**68**	**31**	**22**	**2659**

*In-Pers. Q. = In-person Query

Source: Authors.

Table 2b. Queries made – Groups without Aesthetic

Year	Sem	In- Pers. Q.*	Q. via Whatsapp				Avg
			Txt	Audio	Pic	Video	
2015	I	47	167	39	19	85	357
	II	65	255	40	11	63	434
2016	I	87	253	31	21	62	454
	II	44	303	54	28	82	511
2017	I	36	405	62	31	52	586
	II	28	336	34	31	63	492
2018	I	36	278	38	38	74	464
	II	55	290	36	29	75	485
Total		**398**	**2287**	**334**	**208**	**556**	**3783**

*In-Pers. Q. = In-person Query

Source: Authors.

Table 3. Quantitative results - partial evaluations and final exam Source: Own elaboration

Year	Sem	G with A		G without A	
		MA	FE	MA	FE
2015	I	4,3	4,0	3,2	3,4
	II	4,2	4,5	3,1	3,5
2016	I	4,6	4,6	3,4	3,2
	II	4,4	4,6	3,3	3,2
2017	I	4,5	4,7	3,4	3,4
	II	4,2	4,3	3,1	3,3
2018	I	4,2	4,3	3,1	3,2
	II	4,1	4,2	3,0	3,1
Averages		**4,3**	**4,4**	**3,2**	**3,3**

MA = Midterm average; FE = Final Exam

Source: Authors.

Since just the most frequent factors were selected, the total of students in Table 4 does not match the total of students who participated in this study.

The two factors with the highest frequency were selected in each group, given the matching responses. For this purpose, the students were allowed to stay alone in the classroom, so that they could feel completely free; they were even allowed to talk with their classmates.

The two factors selected, given their high frequency in the students' opinions were F1+ use of aesthetics on the board, F2+ drawings and graphics that are easy to understand. On the other hand, the selected negative factors were their antipodes, that is, F1 - lack of aesthetics on the board, F2 - drawings and graphics that are hard to understand (according to the same student's opinions).

Discussion

According to the data shown in Table 1, it could be concluded that the quantity of students selected to participate in this study and the time devoted to the process are sufficient, since the process was carried out throughout eight semesters, with a population of 334 students (out of 800 students, approximately). Of this amount, about half of them were present in the research process. This makes it possible that the inferences made concerning this student population are solid enough to enrich the discussion, and that these can be extrapolated both to other courses of the same and other programs.

Table 4. Student opinions

Year	Sem	Positive Factors		Negative Factors		Tot
		F 1	F 2	F 1	F2	
2015	I	11	10	12	10	43
	II	9	11	12	9	41
2016	I	11	10	12	9	42
	II	12	8	12	8	40
2017	I	9	7	11	6	33
	II	10	9	12	7	38
2018	I	12	8	13	7	40
	II	11	9	13	7	40
Total		**85**	**72**	**97**	**63**	**317**

Source: Authors.

Tables 2a and 2b show a very interesting scene: the amount of doubts expressed by the students to their teacher was reflected, either in person or via Whatsapp, which was the only service analyzed in this study, although the use of email was also enabled but not used frequently enough so as to statistically affect the results. In so far as the amount of students' personalized queries in the G with A, it was overwhelming, since there were 2.298 queries in comparison with the 398 from G without A. It could be thought that, for the students of today, it is more difficult to express doubts through a service with which they feel more comfortable.

This supposition is confirmed by reviewing the queries made via Whatsapp, since the higher results correspond to the groups where the master class was used without an important aesthetic component on the board. The queries made by this group using text, audio, pictures, and video correspond to 2.287, 334, 208, and 556 respectively, while the queries made by the students in G with A correspond to 240, 68, 31, and 22 in the same items.

This somewhat suggests that a higher number of queries were generated when the aesthetic elements on the board were absent than when they were present, considering that the groups were selected at random. It is worth noting that, in both groups, the highest percentage of queries were made using Whatsapp, which seems to be the most utilized and comfortable service for the students.

Table 3 shows an approximation of the quantitative results of the grades collected in the written midterm evaluations. The difference is noticeable (with a value higher than 1), and it favors those stu-

dents belonging to G with A. In each item (average of midterms and average of final examinations), the quantitative advantages were always and overwhelmingly higher than in the group where the master class strategy was not based on the aesthetic use of the board. Here, it is worthwhile remembering that a great effort was made to make the written evaluations similar in their content both in form and in substance. Finally, Table 4 shows the students' opinion with respect to the most important positive factors that had favored their learning process, and the most important negative factors that had made their learning process difficult. Curiously enough, the two positive factors chosen by most students correspond to the negative factors which made their learning process difficult. According to the students, it is very important to keep the aesthetics on the board, and the drawings and graphics sufficiently didactic and understandable.

Conclusions

According to the general approach of the present study, it can be concluded that, in a computer programming course belonging to a Systems and Computer Engineering program – as evidenced in the results – master classes are strengthened if aesthetic elements are adopted for the order and presentation on the board. According to the results, this seems to be a determining factor in the learning process, since the aesthetic component depends not only on what the students write down on the notebook (students usually note down on their notebooks exactly what they see on the board) but also on what they understand from the theory. In any way, the high level of comprehension resulting from the master class through the aesthetic use of the board cannot be ignored, as well as the resulting number of doubts, and this makes the process dynamic when the aesthetic element is not present. Both forms of presentation of information have great advantages for the feedback process implied in learning.

It would be enriching to extend this study to comprise other fields and even other programs, in order to carry out a continuous analysis to compare the respective results with those obtained in this study. Once the aim of this research has been reached, it would be desirable to encourage soft skills among engineering teachers, such as appropriate distribution on the board, the use of the good handwriting, appropriate use of color markers, a good use of tools for the construction of geometric figures, good skills to draw artistically, and a good general presentation when the utilization of the Cartesian plane is required as reference.

Regarding the aim of this study, it could be argued that it has been accomplished, and that, according to the results obtained, learning from the incorporation of aesthetic elements on the board to enhance the master class was much more effective than learning based on the counterpart experience.

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REVISIÓN DE TEMA

Taxonomy of Outsourcing Alternatives Through Systematic Literature Review

Taxonomía de las alternativas de outsourcing mediante revisión sistemática de literatura

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Abstract

Objective: To facilitate supply chain management and decision-making processes. The case of Latin America as an outsourcing option is analyzed to illustrate its application.

Methodology: A taxonomy supported in Systematic Literature Review is presented to determine the logistics outsourcing strategy that a company or supply chain should develop, along with the alternatives of offshoring and nearshoring. To determine the decision criteria, a literature review is carried out and a characterization of the central criteria of the two strategies is provided.

Results: The offshoring alternative usually provides benefits related to lower manufacturing costs and is ideal for mass production. On the other hand, nearshoring is focused on greater flexibility, which makes it ideal for products with a higher profit margin to exclusive markets.

Conclusions: Currently, Latin America seems a great option for both offshoring and nearshoring, especially for the US, Canada, and European countries. To make this possible, governments and companies have to reformulate their political-private growth strategies focused on clear plans that promote the development of productive, logistical, technological, and innovation capacities, as well as the promotion of foreign investment, educational and scientific development, and the growth of regional demands.

Financing: Universidad Pedagógica y Tecnológica de Colombia (UPTC).

Keywords: Nearshore, Offshore, Onshore, Outsourcing.

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Resumen

Objetivo: Facilitar la gestión de la cadena de suministro y los procesos de toma de decisiones. Se analiza el caso de América Latina como opción de outsourcing para ilustrar su aplicación.
Metodología: Se presenta una taxonomía soportada en *Systematic Literature Review* para determinar la estrategia de outsourcing logístico que debe desarrollar una empresa o cadena de suministro, entre las alternativas de deslocalización y *nearshoring*. Para determinar los criterios de decisión, se realiza una revisión de la literatura y se proporciona una caracterización de los criterios centrales de las dos estrategias.
Resultados: La alternativa de *offshoring* suelen brindar beneficios relacionados con mayores capacidades productivas que inciden en menores costos de fabricación, lo que la hace idónea para la producción de productos masivos. Las ventajas de *nearshoring* se centran en una mayor flexibilidad, lo que lo hace idóneo para la producción de productos con mayor margen de utilidad a mercados exclusivos.
Conclusiones: Latinoamérica aparece en el momento como una gran opción tanto para *offshoring* como para *nearshoring*, especialmente para EE.UU., Canadá y los países Europeos. Para esto, los estados y las compañías deben reformular sus estrategias de crecimiento político-privado centrado en estrategias claras que promuevan el desarrollo de capacidades productivas, logísticas, tecnológicas y de innovación, el fomento a la inversión extranjera, el desarrollo educativo y científico, y el crecimiento de las demandas regionales.
Financiación: Universidad Pedagógica y Tecnológica de Colombia (UPTC).

Palabras clave: Nearshore, Offshore, Onshore, Outsourcing.

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INTRODUCTION

The economic and social dynamics of globalization processes and the consequent foreign investment have led companies and governments—including Latin America to reformulate their growth strategies. This implies the advancement of productive efficiency, innovation, human capital competitiveness, and market internationalization processes. Otherwise, the region may not be able to reach the productivity levels of developed economies within adequate time table works (Ruiz-Arranz *et al.*, 2018). Given the characteristics of organizations in the region, small- and medium-sized enterprises (SMEs) might constitute important factors within these social and economic processes, especially considering their large numbers and impact as the first source of employment in these countries (Liesch & Knight, 1999, Oviatt & McDougall, 2004).

For the decision makers of a company, the choice to outsource operations is important and complex since it affects the whole supply chain and affects both the investing company and the hosting country (Bunyaratavej *et al.*, 2008). Investing in foreign countries brings about the basic benefit of opening new markets and lowering logistic and manufacturing costs, and it represents changes in profitability and market position (Gylling *et al.*, 2015). However, outsourcing also implies some risks such as governability reduction and normative, and social and political instabilities, among others. Likewise, social and political costs are involved, especially regarding employment reduction in the country of origin. For their part, the economic costs involve the identification and operation of the company in the new country (Eden & Miller, 2004). It is worth mentioning that outsourcing is not only associated with goods but also services, which have become an important investment and development source in emerging economies.

Nearshoring and offshoring are two different outsourcing modes for companies and characterize by contrasting geographical locations. While offshoring refers to outsourcing in distant countries from the headquarters of the company, nearshoring is adjacent outsourcing, (i.e., it takes place in neighboring countries with shared geographical limits and cultural affinity) (Bock, 2008).

Both nearshoring and offshoring constitute supply chain logistic and productive strategies with profound implications on the profitability and operation of a business within the larger network wherein it is immersed (García Cáceres & Escobar, 2016, Riopel *et al.*, 2005, Rodado *et al.*, 2017). The selection of a pure or mixed alternative is of particular interest in supply chain management contexts, both in theoretical and applied contexts. According to (Hahn *et al.*, 2011), although services and production processes (especially nearshoring) are considered important and contemporary topics in the study of supply chain management, they have not been sufficiently studied. (Kedia & Mukherjee, 2009) acknowledge this as a sensitive decision which should be based on the type of activities to be offshored and the relative importance of the specific hosting country and its human capital.

METHODOLOGY

The current work is structured as follows: First, a review of the literature on the topic highlights the central characteristics of outsourcing strategies; second, a novel development is introduced, which determines the criteria to be considered in this type of decision; third, an outsourcing decision model and its corresponding test compare nearshoring to offshoring in Latin America; and, finally, conclusions and recommendations are drawn.

This work is supported in the Systematic Literature Review (Xiao & Watson, 2019) whose deployment is presented below.

- Search the literature
- Extract data
- Analyze and synthesize data
- Report findings

SEARCH THE LITERATURE

Offshoring

Since the early 1990s, regardless of the adopted governance mode, offshoring has become one of the most widely implemented strategies on the part of western manufacturing companies to maintain or enhance their competitive advantage (Contractor *et al.*, 2010). These strategies are primarily based on scale economies resulting from the high manufacturing capacities, low cost and increasing skillfulness of offshored labor, which can be specially found in Asian countries with large populations.

Offshoring (also known as "offshore sourcing") has been defined as the outsourcing alternative in which the activities that an organization subcontracts, including both manufacturing and services, take place in a distant foreign country with a significantly different culture (Di Gregorio *et al.*, 2009, Kehal & Singh, 2006, Schmeisser, 2013). As a management practice, offshoring originated in the late seventies (Lewin & Peeters, 2006). For example, India and China can be considered "offshore"for both the United Kingdom and the United States. In essence, offshoring refers to the cross-border relocation of a firm's value chain activities, which were once carried out somewhere like the firm's home country, to distant locations, seeking to serve an increasing global demand (Doh *et al.*, 2009, Lewin *et al.*, 2009, Pfannenstein & Tsai, 2004, Stephan *et al.*, 2008). This practice has been associated with an overall economic benefit in terms of productivity, quality, and customer satisfaction. As companies face strong pressure to reduce costs and improve efficiency, offshoring has become one of

their most popular operational strategies (Gottfredson *et al.*, 2005). However, it poses significant challenges (Levy, 2005) arising from cultural barriers related to different ways of doing business in the countries involved. These issues can negatively affect asset ownership, management control, or intellectual property (Lampel & Bhalla, 2011). Besides, there are other economic risks such as production and logistic process halts and the loss of innovative inertia in the production process, among others.

Offshoring opens new opportunities for different-sized companies seeking to transcend from regional to global domains. The availability of low-cost communications, the commercialization of technologies, and the ease of access to global human resources have allowed many companies to implement offshore services in cheaper emerging markets (Donaldson, 2014).

Nearshoring

An emerging trend against offshoring has been observed mostly in the last decade. Some companies that had moved their production to distant nations have brought it to their home or neighboring countries (Ellram *et al.*, 2013, Kinkel, 2012). The literature has not sufficiently explored this emerging alternative, even though companies locate approximately one in five overseas projects in a nearshore location (Hahn *et al.*, 2011). According to (Bock, 2008), nearshoring is outsourcing located in neighboring countries with shared geographical boundaries and/or economic and social similarities. These shared aspects facilitate the adaptation of the new location in aspects such as language, culture, and respect for intellectual property, among others.

Nearshoring is characterized by two primary components, namely physical proximity and trade agreements, which promote the integration of the countries and the regional economy (Hahn *et al.*, 2011). According to these authors, said integration not only facilitates access to services and productive capacity investments in the destination country, but also removes transaction cost barriers. Likewise, they consider that shared legislation features smooth the mobility of human talent between countries.

The practice of nearshoring selects locations that are not thought to represent the highest cost savings but do bring about staff mobility savings and lower risks. Interest in nearshoring is manifold: Taking advantage of technical knowledge; lack of language barriers with local workers and clients (who therefore are more likely to understand cultural aspects); and shared time zones. All these aspects facilitate the whole coordination of operations. In this way, companies generally maintain similar socioeconomic and political conditions, which reduces risk-control-related costs in the practice of nearshoring as compared to offshoring.

Whereas nearshore locations may be less prone to significant changes in the business environment, companies may reassess offshore plans due to certain concerns (Drezner, 2004). For example, considerations about the quality and reliability of some services, as well as infrastructure deficiencies in locations such as India, make it difficult to keep pace with demand.

Table I. Offshore, Nearshore and Onshore compared production of a pair of Jeans

Outsourcing mode	Case	Location	Transport time (days)	Cost USD	China (base case)
Offshoring		Bangladesh	30	10.68	-11 %
		China	30	12.04	0 %
Nearshoring	USA	Mexico	2	10,57	-12 %
Onshoring		USA	na	14,05	17 %
		Bangladesh	30	9,94	-20 %
Offshoring		China	30	12,46	0 %
Nearshoring	Germany	Turkey	3-jun	12,08	-3 %
Onshoring		Germany	na	30,36	144 %

Source: The authors.

However, determining the right strategy is a complex decision. In this regard, table **I** shows the calculated cost of producing a pair of jeans and importing them to the USA or Germany as framed in the different outsourcing strategies in question: Nearshoring, offshoring and onshoring (the latter can be seen as an extreme case of nearshoring, i.e., producing in the home country). The results show that for Europe the unit costs are significantly lower when manufacturing in Bangladesh (offshore) than in Turkey (nearshore). Contrarily, in the case of the US production costs in Mexico (nearshore) are a little lower than in Bangladesh (offshore), and delivery time reduces from 30 to 2 days.

A consulting study on the topic (Andersson *et al.*, 2018) allowed for the rejection of the hypothesis that offshoring minimizes costs in and of itself. Instead, it is necessary to conduct rigorous analyses of outsourcing alternatives on a case-by-case basis, addressing economic, productive, and sustainability considerations.

Extracting data

Contrasting nearshore and offshore strategies

The following is a review of the literature on the topic, seeking to deepen the study of the criteria and conditions that influence the decision to undertake offshoring or nearshoring strategies.

Service offshoring, commonly defined as the international relocation of service provision, has become a relevant phenomenon in business. (Pisani & Ricart, 2016) have systematically reviewed, mapped, and evaluated the literature on the topic. A total of 79 studies conducted between 1990 and 2014 have been identified and analyzed from a selected group of 14 scientific journals.

(Lahiri & Kedia, 2011) provide an integral framework outlining various institutional and organizational factors that co-evolve to enable the participation of clients and suppliers in an offshore operation. Thus, customers must help suppliers to co-evolve as long-term business partners, while suppliers must address sources of concern related to high levels of labor turnover, insufficient generation of mid-level managers, and inadequate security measures. An offshoring analytical framework (Kedia & Mukherjee, 2009) suggests that companies should embark on the strategy when they perceive three interrelated sets of advantages: Disintegration advantages (D), location-specific supply advantages (L) and externalization advantages (E). These result in the Disintegration-Location-Externalization (DLE) framework. Companies tend to embark in offshoring strategies only when they perceive location-specific advantages in the form of supporting infrastructure, low wage rates or better quality of intellectual capital (ibid.).

In surveying and evaluating current nearshoring practices and prospects in the Baltic region, (Slepniov *et al.*, 2013) observed that small distances, both geographical and psychological, play an important role in the location of business branches. For instance, they found that the European Union has focused nearshoring practices in places such as the Czech Republic, Hungary, Poland, and the Baltic countries, whereas the United States is increasing nearshoring operations in Mexico, Costa Rica, and even Canada.

Nearshoring requires the possibility to save on freight tariffs and customs duties when exporting to closer countries (Andersson *et al.*, 2018). (Ruivo *et al.*, 2015) have introduced a policy development framework to enable the growth of nearshoring IT services. (Pranto & Coelho, 2019) compare nearshoring to offshoring IT service outsourcing through analysis by the proximity-based delivery method.

(Panova *et al.*, 2016) have identified and analyzed factors that support European manufacturing nearshoring or offshoring towards Russia and China. They consider factors such as labor cost, inflation, exchange rate, and labor productivity, which are analyzed through deterministic models to identify logical dependencies.

The development of the decision model introduced by the present work implies, in the first place, the characterization of the two outsourcing strategies in question. For this purpose, a detailed comparison was carried out between the available outsourcing alternatives for the US, which may correspond to Latin America (nearshoring) and Asia (offshoring). Said contrast was established through a series of relevant aspects: Labor and productive capacity, political risk, resource funding, infrastructure, education, business culture, costs, operational risks, taxes, intellectual property, cultural affinity, operational control, and energy costs (table **II**).

Table II. Comparison between nearshoring and offshoring

Criterion	Offshoring	Nearshoring
Location distance	Longer distance to destination country	Shorter distance to destination country
Labor and productive capacity.	Cheaper and highly qualified.	Cheaper than the US, but more expensive than Asia.
Governmental policy	Varies across countries, from lower to higher values of specific indicators (see Table III).	Usually high, with few exceptions (Venezuela).
Personnel rotation	Strong competitiveness leading to higher rotation.	Usually a more stable labor force, but less productive than in the USA, India, or China.
Technological infrastructure	Varies by country. Susceptible to natural phenomena and availability of infrastructure. Elevated telecommunication costs to and from the US.	It is usually very good but also susceptible to natural phenomena and infrastructure availability (i.e., electric power)
Education	Strong cultural differences with western education. Medium to high educational quality.	Western education, more adjusted to American than Asian culture. High to low educational quality. On average, it is lower than Indian or Chinese education.
Organizational culture	Medium adaptability to American business culture. Medium to low compatibility with the American political system.	Similar to Western culture. Most companies are driven by the Western calendar of activities.
		High to medium compatibility with the US political system.
Production costs	Low production costs. Elevated logistic costs.	Medium production costs. Low logistic costs.
Tax rates.	Low customs duty fees. Medium regulatory, and social and economic instability.	Low customs duty fees. Medium regulatory, social and economic instability. There are no special regulatory constraints.
Respect for intellectual property rights	High to medium risk of industrial espionage.	Low risk of industrial espionage.
	High to medium risk of intellectual property right violation.	Low to medium risk of intellectual property right violation.

Table II continued from previous page

Criterion	Offshoring	Nearshoring
Cultural affinity	Low to medium. Culture, political system, and religion are significantly different from those of the USA.	High. Culture, political system, and religion are similar to American ones in most cases.
Operative control	Medium. Shared property in the case of China. In the other countries, there are property rights.	High operative and managerial control.
Energetic costs	High. Great dependence on external fossil fuels.	Medium to low. High availability of thermoelectric energy.
Resource cooperation among companies	Low. Building strategic alliances with destination countries is tough, especially due to lack of confidence for product development.	Medium to low. Building strategic alliances with destination countries is difficult, especially due to the non-alignment of key technological competencies in product development with Latin American companies.
Linguistic ability	High to low in India. Low to medium in China.	Higher linguistic ability than most Asian countries, especially China. Lower than India.
Timely delivery rates	Medium to high. Due to long distances, timely delivery rates are higher and more susceptible to logistic breakages.	Proximity with destination countries and shared ways of doing business. However, there is low regulatory stability for business conduction.
Ease of doing business	Differences in culture, economy, political ideology, and business practices can be difficult to overcome.	Proximity with destination countries and shared ways of doing business. However, there is low regulatory stability for business conduction.
Availability of raw materials	Most raw materials are lowly available.	Most raw materials are highly available.
Local currency strength	High. Asian currencies are usually strong.	Medium. Latin American currencies are relatively weak.

Source: The authors.

Analyzing and synthesizing data

Outsourcing location decision

This section introduces the current outsourcing models or decision frameworks as found in the literature.

Using Data Envelopment Analysis (DEA), (Bunyaratavej *et al.*, 2008) examined the offshore service attractiveness of hosting countries. They assessed which of them used their resources or inputs more efficiently to produce attractive offshoring outputs. They found that China, India, Ireland, the Netherlands, Pakistan, Slovakia, Spain, and the United Kingdom are particularly attractive locations, since they stand out in at least one of the key competence variables for creating input related efficiency (DEA inputs): Wages, education, and infrastructure (ibid.).

(Bock, 2008) states that, unlike the wage savings factor, which is easy to estimate, costs resulting from lower worker skills in potential outsource locations are difficult to estimate. This author proposes a model that considers the salary level, the different types of collaborators and their working skills as important outsourcing location decision-making factors. In analyzing surveyed data, (Ellram *et al.*, 2013) explored factors affecting the location decisions of organizations, who were observed to give more weight to supply chain issues and strategic factors.

(López & Ishizaka, 2019) proposed a model based on Fuzzy Cognitive Maps (FCM) and Analytic Hierarchy Process (AHP). The model allows estimating the impact of the location decision on the offshore outsourcing process. (Gerbl *et al.*, 2015) developed a BPO (Business Process Outsourcing) structure by integrating certain characteristics of the company (internal availability of resources and capacity to outsource clients) with the attraction factors of a given location (distance, human capital, and government policy) to choose between onshoring, nearshoring, and offshoring.

In summary, the current literature review shows few works addressing the problem of outsourcing through decision support systems. This is certainly a relevant deficiency, especially considering that mathematical programming and multi-criteria decision methods, which constitute steadily developing basic and applied research fields, can aid such systems. The criteria considered in outsourcing decisions are presented in table **III**.

The multi-criteria decision process proposed in this paper gathers at least 20 criteria to which the decision makers usually refer when selecting between nearshore and offshore outsourcing alternatives (table **IV**). The table presents the level of favorability (+ or -) of the different criteria for each of the decision alternatives, under the dominant conditions during the study. Said favorability must be assessed by the decision makers of the companies as they apply it to the countries where the outsourcing strategy is to be developed.

Table III. Outsourcing decision model

References	Criterion	Indicator	Nearshoring	Offshoring
(López & Ishizaka, 2019), (Kedia & Mukherjee, 2009), (Lahiri & Kedia, 2011), (Graf & Mudambi, 2005), (Bunyaratavej *et al.*, 2008).	Technological infrastructure	Infrastructure quality	-	+

Table III continued from previous page

References	Criterion	Indicator	Nearshoring	Offshoring
(López & Ishizaka, 2019), (Kedia & Mukherjee, 2009), (Gerbl *et al.*, 2015), (Graf & Mudambi, 2005), (Bunyaratavej *et al.*, 2008).	Governmental policy	Political Stability Index	+	-
		Control of corruption.		
		Government Efficiency		
(López & Ishizaka, 2019), (Bunyaratavej *et al.*, 2008).	Cultural affinity	Affinity level	+	-
(López & Ishizaka, 2019).	Tax rates	Actual amounts to be paid as taxes	-	+
(López & Ishizaka, 2019).	Linguistic ability	High linguistic ability	+	-
(Boardman Liu *et al*, 2008), (Kedia & Mukherjee, 2009), (Lahiri & Kedia, 2011), (Amiti & Wei, 2009), (Dibbern *et al.*, 2008), (Farrell, 2005), (Bunyaratavej *et al.*, 2008).	Production costs	Marginal production cost	-	+
(López & Ishizaka, 2019), (Boardman Liu *et al*, 2008)	Timely delivery rate	% of orders delivered in time	+	-
(Buss & Peukert, 2015).	Respect for intellectual property rights	% of violated patents	+	-
(Gerbl *et al.*, 2015).	Easiness for doing business	Level of easiness	+	-
(Ho *et al.*, 2012), (Gerbl *et al.*, 2015), (Kedia & Mukherjee, 2009), (Lahiri & Kedia, 2011), (Stephan *et al.*, 2008), (Lewin *et al.*, 2009), (Graf & Mudambi, 2005), (Bunyaratavej *et al.*, 2008)	Labor and productive capacity	Performance level	-	+

Table III continued from previous page

References	Criterion	Indicator	Nearshoring	Offshoring
(Gerbl *et al.*, 2015).	Location distance	Km	+	-
(Kedia & Lahiri, 2007), (Kedia & Mukherjee, 2009), (Mudambi & Tallman, 2010), (Tallman & Fladmoe-Lindquist, 2002), (Vivek *et al.*, 2009).	Resource cooperation among companies	Level of cooperation	+	-
(Bock, 2008), (Hahn *et al.*, 2011).	Operative control	% of compliance with procedures established by the company	+	-
(Bunyaratavej *et al.*, 2008).	Education	% of literacy, Coefficient of Effectiveness	+	-
(Lahiri & Kedia, 2011)	Personnel rotation	% of personnel rotation	+	-
(Copuš *et al.*, 2019).	Organizational culture	Degree of motivation of employees	+	-
(Kamal *et al.*, 2019).	Energy costs	Energetic intensity	+	-
		Energetic efficiency		
(Ferro & Bonollo, 2019).	Raw material availability	Raw material inventory levels	+	
(Shahzad *et al.*, 2018).	Local currency strength	Big Mac Index Gross Domestic Product (GDP) CICR system (Currency Index Cross Referencing)		+

Source: The authors.

Report findings

The Latin American case

India, China, Taiwan, and Malaysia are the main centers of global outsourcing (Javalgi *et al.*, 2009). In recent years, countries from Latin America, Africa and the Middle East have been increasing their participation in outsourcing processes (Bianchi *et al.*, 2019). As regards the Latin American case, coun-

tries such as Argentina, Brazil, Chile, Colombia, Peru, and Mexico have been carrying out outsourcing processes in recent years, with a particular emphasis on IT services (Vidal & Correa, 2007).

Table IV. Conditions for doing business in Latin America

Criterion	Advantages	Disadvantages	Nearshoring	Offshoring
Location distance	Geographical proximity with the United States and Canada; relative proximity with Europe. Similar time zones.		+	
Cultural affinity	Cultural affinity with the United States		+	
Language skills	Portuguese and Spanish skills, having English as a second language		+	
Power costs	Adequate energy infrastructure		+	
Government policy		State and private corruption		+
Tax rates	Significant tax incentives		+	
Labor and productive capacity	Lowly competitive labor		+	
Technological infrastructure		Medium communications infrastructure		+
Production costs	Low and medium cost labor		+	
Raw material availability	Abundant raw material sources		+	
Respect for intellectual property rights	Medium to high respect for intellectual property depending on the country			
Ease to do business		Similar business doing styles, although contrasted by high regulatory instability		+
Local currency strength		Weak regional currencies		+

Table IV continued from previous page

Criterion	Advantages	Disadvantages	Nearshoring	Offshoring
Timely delivery rate	Timely delivery due to proximity with the USA		+	
Operative Control	Strong operative managerial control		+	
Education	Western education, strong ties and good understanding of USA commerce		+	
Organizational Culture.	Similar to western culture. Most companies follow the western calendar.		+	
Personnel rotation.	Usually a more stable labor force.		+	
Resource cooperation among companies	Similar time zones and cultures facilitate alliances among companies		+	

Source: The authors.

Latin American governments are currently promoting foreign investment through tax benefits. Although they have trained human capital and labor at reasonable costs, they lag in logistics, regulatory stability, and corruption levels. Nevertheless, North American and Western European firms have found an attractive nearshore or offshore destination in Latin America, especially due to cultural and ideological affinity and a remarkable ease of negotiating terms. In this regard, the outsourcing industry in Latin America is growing faster than in other regions (Bianchi *et al.*, 2019). This part of the continent is the third most popular destination in the world for outsourcing services or processes (KPMG, 2009). Among the nearshoring criteria for Latin America are costs, technology, skilled labor, economic stability, proximity to the U.S. and Europe, English and Spanish skills, and time zone alignment with the U.S. and Canada (Honeycutt *et al.*, 2012).

In terms of competitiveness, the region is highly heterogeneous. According to (Drezner, 2004), there are differences related to competitiveness, especially regarding institutions, infrastructure, labor markets, and innovation. Countries like Chile, Panama and Costa Rica have received the highest scores, while countries like Venezuela, Paraguay and El Salvador have got the lowest scores in the region for the different dimensions of the Global Competitiveness Index (GCI) 2017-2018. Intra-regional differences in terms of competitiveness are significant. While Chile ranks 33 among the 137 nations included in the GCI, Venezuela ranks 127. Globally, Latin America exhibits the greatest intra-regional

differences (Drezner, 2004). Table **IV** summarizes the conditions for doing business in Latin America as an outsourcing alternative.

RESULTS AND CONCLUSIONS

Offshoring usually brings about higher production capacities and lower manufacturing costs, which make this an ideal strategy for large scale production. The advantages of nearshoring have to do with its greater flexibility, which makes it ideal for the manufacturing of high utility margin products for exclusive markets. Despite this production logic, the concentration of manufactures from all the world in certain regions, particularly in China, has generated controversy. This is due to multiple reasons that ultimately go beyond production and link to politics and macroeconomics.

The contrast shows that the decision must be made in a holistic manner and in a longer-term than usual. Just as well, it must focus on both the productivity and sustainability of enterprises and supply chains.

The present paper focuses on the development of a taxonomy that identifies relevant criteria affecting outsourcing decisions in an integral context linking administrative, legal, productive, political, and cultural dimensions. This context provides the input for decision support systems linked to MCDM (Multicriteria Decision Making) techniques. Given the strategic nature of public decisions and the importance of investment in these environments, special attention is paid to them. The decision makers must determine the relevance of the criteria to adequately interpret the results of the support systems and make more technical decisions.

In this sense, a series of aspects must be taken into consideration: Managerial control, respect for intellectual property, operative risk, product mixing in different factories around the world, strategic alliances with different suppliers in global and regional contexts and, finally, the balance between productive costs and logistic and electric power costs. In contemporary socio-political settings, corporate decisions are likely to be affected by political choices at national and economic block levels.

Latin America has become an attractive nearshoring and offshoring option, especially for European and North American countries. For this purpose, nations and companies need to reformulate their growth strategies to promote logistic, technological, productive, and innovative capacities, as well as foreign investment, scientific and educational development, and the growth of demand across regions.

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Instructions for authors

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

CONTENT

Tecnura journal is an institutional publication of the Faculty of Technology from University Francisco José de Caldas. It is a scientific and technological publication with quarterly periodicity, which is published in January, April, July and October. The first issue appeared in the second semester of 1997 and up to now it has maintained its regularity.

The areas of interest of Tecnura journal are focused on all engineering fields such as electronics, telecommunications, electricity, systems, industrial, mechanics, cadastral, civil, environmental, among others. However, it is not restricted to those; it also has room for education and health issues, as long as they are related to engineering. The journal will only publish concerning scientific and technological research, reflection and revision. In consequence, during the initial editorial evaluation, short articles and case reports will be rejected.

Tecnura Journal is addressed for professors, researchers, students and professionals interested in permanent update of their knowledge and follow-up of scientific-technologic processes in the field of engineering. Tecnura Journal has as mission to disseminate results of research projects in the areas of engineering, through the publication of original and unpublished articles, conducted by academics and professionals accredited by public or private national or foreign institutions. Articles submitted to Tecnura journal must be unpublished works written in Spanish or English; nevertheless, preference will be given to articles that show innovative concepts of great interest, related to the objective and scope of the journal.

Tecnura is an academic publication indexed in the Regional Index Scielo Colombia (Colombia) and Redalyc (México); as well as of the following bibliographic databases: INSPEC of the Institution of Engineering and Technology (England), Fuente Académica Premier of EBSCO (United States), CABI (England), Index Copernicus (Poland), Informe Académico of Gale Cengage Learning (México), Periódica from the Universidad Nacional Autónoma de México (México), Oceanet (Spain) and Dialnet from the Universidad de la Rioja (Spain). It is also part of the following directories: Online

Regional Information System for Scientific journals from Latin America, Caribbean, Spain and Portugal Latindex (México), Bibliographic Index Actualidad Iberoamericana (Chile), e-Revistas (Spain) , DOAJ (Sweden) and Ulrich of Proquest (United States).

Tecnura is a journal arbitrated by a revision process among double blind peers. The schedule of the conformation of its scientific and editorial committee is subject to the publication of articles in internationally indexed journals by their members.

District University Francisco José de Caldas, its directors, the editor, the editorial and scientific committee are not responsible for the opinions and the criteria expressed in the content of the articles and they are published under the exclusive responsibility of the authors and do not necessarily reflect the ideas of the editorial committee.

In addition to the printed version, Tecnura journal also has a digital version available in its web page: http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/index

TYPE OF ARTICLES ACCEPTED

According to the classification of the Scientific and Technological Publications National Index (Publindex-Colciencias), Tecnura journal receives nominations of unpublished articles on the following topics:

- **Scientific and technological research articles:** document that presents, in a detailed manner, the original results of research projects. The generally used structure contains four main parts: introduction, methodology, results and conclusions.
- **Reflection articles:** document that presents research results from an analytic, interpretative or critic perspective from the author, dealing with a specific topic and adopting original sources.
- **Review article:** document that results from a research where the results of published or unpublished research on a science or technology field are analyzed, systematized and integrated, in order to state the advances and tendencies in development. It is characterized for presenting a careful bibliographical review of at least 50 references.

ARTICLE FORMAT

About the appropriate language and style for articles writing

- Authors must use simple sentence structures, avoiding those too long or complex.
- The vocabulary used must be basic and common. Technical language must be briefly explained; also, the meaning of the acronyms must be given the first time they appear in the text.
- The authors are responsible for their work to be conducted in a professional and ethic manner.

About the length of articles

The articles should not exceed 25 pages in letter size and double space, with symmetric margins of 3 cm. Only in the case of review articles, these 25 pages do not include references.

About the presentation format

Submitted articles must be unpublished works written in Spanish or English, and must be typed in Microsoft Word (2003 and beyond), complying with the following indications:

- *Times New Roman* letter, 12 point (except it is required for some sections).
- One column, double-spaced.
- All the margins 3 cm.
- Paragraphs should be justified without spaces between consecutives and without cutting words.
- Do not include page breaks or section finals.
- If you want to emphasize words or phrases from the text, do not use bold letters but italic.
- Decimals should be pointed with comma (,) and not with period (.).
- Thousands and millions should be pointed with a fine space.
- Avoid footnotes.
- Arabic nomenclature must be used only until the third level.

About the article structure

The papers must have the following structure and comply with the following requirements:

Composition of an article

All the articles submitted for evaluation and possible publication by the Tecnura Journal must have at least the following components:

- Title in Spanish and English.
- Information about the authors.
- Abstract in Spanish and English.
- Key words in Spanish and English.
- Introduction.
- Conclusions.

- Future work (optional).
- Acknowledgements (optional).
- Bibliographical references.

If the article is related to scientific and technological research must have, in addition to the above, the following components:

- Methodology.
- Results.
- Financing.

Title

The title of the article must be short or divided in title and subtitle, attractive for the potential reader and written in capital letters. It should appear centered between the margins, written in *Times New Roman* letter, in bold, font size 18. The title of the article has to be in Spanish and English separated by double space. Maximum 20 words.

Authors

After the title the complete name(s) of the author(s) must be written, with their basic biographical data: undergraduate degree, graduate degree, occupation or position, institutional affiliation (institution where they work), dependency, city, country and e-mail. The above information must be immediately below the author's name.

Abstract

The scope and purpose of the work must be established giving a clear and concise description of the methodology, results presented and the conclusions obtained. Maximum of 250 words.

Keywords

Between three and ten keywords must be chosen, written in English with *Times New Roman* letter in bold and italic.

Key words must be written in alphabetic order and must be as standard as possible, for which it is suggested the use of international databases accor- ding to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the IEEE thesaurus and World Bank thesaurus that can be accessed at the following web pages respectively:

http://www.ieee.org/documents/2009Taxonomy_v101.pdf

http://multites.net/mtsql/wb/site/default.asp

Abstract in Spanish

Translation to the Spanish language of the text that appears in the abstract, it must be correct and precise.

Keywords in Spanish

Translation to the English language of the keywords in Spanish, they must be correct and precise.

´ Keywords must be written in the order of the English version and must be as standard as possible, for which it is suggested the use of international databases according to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the UNESCO thesaurus that can be found at the following web pages:

http://databases.unesco.org/thessp

Introduction

The general idea of the work must be described, its context, backgrounds, state of the art of the topic, objectives and possible scope of the work.

Methodology

The writing of this part must allow any specialized professional in the topic to replicate the research.

Results

Explanation and interpretation of the findings. If necessary, a brief discussion focused on the interpretation of the results can be presented.

Conclusions

Implication of the results and their relation to the proposed objective.

Financing

Mention the associated research from which the article was derived and the entity that endorsed and financed the research.

Acknowledgments

They should preferably be brief and include the essential contributions for the development of the paper.

Equations

Equations must appear centered with respect to the main text. They must be referenced with consecutive numbers (written in parenthesis close to the right margin). Equations are cited in the main text employing the word equation, and followed by the number in parenthesis. Equations must be made in an appropriate equation editor and compatible with "InDesign" software, as for example the equation editor of Windows.

Tables

In the case of implementation of tables, it is recommended that these are not inserted as images, considering that in that format they cannot be modified. The title of each table must include the word table (in italic) followed by the corresponding consecutive number and a brief name of the table. The heading must be written in TNR letter, italic and font size 9.

Charts are not presented but tables and they should be automatically raised from the text processor. Tables should be named and referenced in the article, in strict order. Every table must have at the bottom the source from which it was taken, or to mention self-authorship if it is the case.

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All the figures or pictures have to be sent in JPG or PNG format with a minimum resolution of 300 DPI, adapted to gray scale.

The footnote or name of each figure must include the word figure (in italic) followed by the corresponding consecutive number and a brief description of the content of the figure. The footnote of the figure must be written in Times New Roman letter, italic and font size 9. Figures must be named and referenced in the article, in strict order. Every figure must have at the bottom the source from which it was taken, or to mention self-author-ship if it is the case.

Symbols

The symbols of the constants, variables and functions in Latin or Greek letters –included in the equations- must be in italic; the mathematical symbols and the numbers do not go in italic. The symbols must be identified immediately after the equation. Units, dimensions and symbols of the international system must be used.

When using acronyms or abbreviations, the complete equivalence should be written first, followed by the corresponding acronym or abbreviation in parenthesis and from there it is only written the respective acronym or abbreviation.

Bibliographic references

The adopted reference citation style by Tecnura journal is APA sixth edition. The cites, bibliographic references and infography are included in the last part of the article. The bibliographic references must be alphabetically ordered according to the author's first surname, without numbering.

There should only appear the cited references in the main body of the work, in tables or in figures.

It means, in the list there should not appear other references although they have been consulted by the authors for the work preparation. We suggest using tools such as: Cites and bibliography from Microsoft Word (for APA sixth edition version 2013 or superior), Zotero, Mendeley, among others.

The call for a bibliographic reference is inserted in the text, at the pertinent point, under certain characteristics:

- If the sentence includes the author's surname, it should only be written the date into a parenthesis, for instance:
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- When the author is not included in the sentence, surname and date must be into a parenthesis. La investigación de materiales dio una visión en el área (Martínez, 2012).
- If the document or work has more than two authors, the first cite must include all the surnames. 1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) ....
- In the following mentions, it must only be written the author's first surname, followed by "et al.". En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que ...
- When the document or work has more than six authors, it must be used from the first mention "et al.".

Next it is described a series of examples of the more used references, according to the reference style adopted by Tecnura journal:

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Report from a Government agency

Federal Interagency Forum on Child and Family Statistics. America's Children: Key National Indicators of Well-Being, 2009. Washington, DC: U.S. Government Printing Office. Recuperado de http://www.childstats.gov/pubs/index.asp

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The article has to be submitted with an information format about the article and its authors which can be downloaded from the web page of Tecnura journal http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/index, in the section "Forms and Documents". It is important to complete all the fields of information requested, some of them have comments to clarify better what is being requested. The format must not be scanned.

Article

Article in digital format (Word 2003 and later editions) that complies with all the presentation rules described in chapter three, "Article structure", of this guide of instructions for authors.

PUBLICATION PROCEDURE

The procedure to be followed by Tecnura journal for the evaluation and possible publication of the papers sent by the authors is the following in chronological order:

1. Delivery of the article with the cover letter and the information format by the authors.
2. Notification to the author about the reception of the article.
3. Verification of the presentation rules by the monitor of the journal.
4. Notification to the author about the evaluation of the presentation rules.
5. Submission of corrections made by the authors related to the evaluation of presentation rules.
6. Submission of the articles to the selected arbitrators.
7. Notification of the beginning of the arbitration process of the article.
8. Notification to the authors about the decision made by the editorial committee, and about the evaluations made by the arbitrators.
9. Delivery of the corrections made by the authors with respect to the evaluations made by the arbitrators.
10. Study of the final version of the article and the evaluations of the arbitrators by the editorial committee.

11. Delivery by the authors of the letter that surrenders right to the editor of the journal.
12. Submission of the version with style corrections and diagramed to the authors.
13. Verification of errors and final approval of the version with style corrections and diagrammed by the authors.
14. Publication of the article in the corresponding number of Tecnura journal.
15. Notification to the authors of the number of interest.
16. Delivery of a copy of the journal to each one of the authors of the published article.

ARTICLE ARBITARION PROCESS

Considering the quarterly periodicity of the journal, the Editorial Committee makes four calls every year for the submission of articles, approximately in the months of February, May, August and November. The articles will be received until the date established in the call.

Once received the articles, the monitor of the journal will make an initial form evaluation to verify the completion of the elements mentioned in this guide of instructions to authors. After receiving again the article with the requested corrections by the journal's monitor, the paper will be submitted to evaluation by three academic peers (through time it is expected to include more external peers to participate in the process).

Each article sent to Tecnura journal is checked by two expert academic peers external to the institution of the authors, by a process of "*Peer-review*" of double blind, guaranteeing the anonymity of authors and evaluators; every paper sent is considered confidential and so it is demanded to evaluators.

Possible conclusions of the result of the evaluation by the judges are only three: publish the article without modifications, publish the article with modifications and not publish the article.

Subsequently, the Editorial Committee takes the decision to publish or not the articles, based on the results of the evaluations made by the assigned arbitrators. In case of contradictions in the evaluations with respect to the publication of an article, the editorial committee will send the article to a third peer and will be inclined for the two evaluations that have the same concept with respect to the publication of the article.

In each call the main author must suggest at least four possible external arbitrators to his work institution evaluators, who must be specialists in the specific topic of the article sent and must have at least Masters level, and at least two must to be international. Potential evaluators can belong to a university or industry, public or private; their complete names must be provided, highest academic formation, institutional affiliation and e-mail. The editorial committee will analyze these four potential evaluators in order to enrich the database of arbitrators of Tecnura journal.

The Editorial Committee of Tecnura journal reserves the right to print, reproduce total or partially the article, as the right to accept or reject it. In the same way, it has the right to make any editorial modification that considers necessary; in this case the author will receive written recommendations from the evaluators. If accepted, authors must deliver the article with the suggested adjustments within the dates given by the journal to guarantee its publication in the programmed number.

CONTACT

For any additional information request, please send an e-mail to Tecnura journal tecnura@udistrital.edu.co, tecnura@gmail.com or by mail to Cesar Augusto Garcia Ubaque, Director and Publisher of Tecnura Journal, to the following address:

Tecnura Journal
Journals Room, Block 5, Office 305.
Faculty of Technology
Universidad Distrital Francisco José de Caldas
Transversal 70 B N. 73 a 35 sur
Phone: 571–3239300 Extension: 5003
Mobile: 57–3153614852
Bogotá D.C., Colombia
Email:
tecnura.ud@correo.udistrital.edu.co, tecnura@gmail. com
Web page:
https://revistas.udistrital.edu.co/ojs/index.php/ Tecnura/index

Instrucciones para los autores

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

CONTENIDO

ALCANCE Y POLÍTICA EDITORIAL DE LA REVISTA

La revista Tecnura es una publicación institucional de la Facultad Tecnológica de la Universidad Francisco José de Caldas, de carácter científico-tecnológico con periodicidad trimestral, que se publica los meses de enero, abril, julio y octubre. Su primer número apareció en el segundo semestre del año 1997 y hasta la fecha ha mantenido su regularidad.

Las áreas temáticas de interés de la revista Tecnura están enfocadas a todos los campos de la ingeniería, como la electrónica, telecomunicaciones, electricidad, sistemas, industrial, mecánica, catastral, civil, ambiental, entre otras. Sin embargo, no se restringe únicamente a estas, también tienen cabida los temas de educación y salud, siempre y cuando estén relacionados con la ingeniería. La revista publica únicamente artículos de investigación científica y tecnológica, de reflexión y de revisión. En consecuencia, durante la fase de evaluación editorial inicial se rechazarán los artículos cortos y reportes de caso.

La revista Tecnura está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científico-tecnológica, en el campo de las ingenierías. Tiene como misión divulgar resultados de proyectos de investigación realizados en el área de las ingenierías, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado. Los artículos presentados deben ser trabajos inéditos escritos en español o inglés; sin embargo, tendrán preferencia los artículos que muestren conceptos innovadores de gran interés, que traten sobre asuntos relacionados con el objetivo y cobertura temática de la revista.

Instrucciones para los autores

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

Tecnura es una publicación de carácter académico indexada en los Índices Regionales Scielo Colombia (Colombia) y Redalyc (México), además de las siguientes bases bibliográficas: INSPEC del Institution of Engineering and Technology (Inglaterra), Fuente Académica Premier de EBSCO (Estados Unidos), CABI (Inglaterra), Index Corpernicus (Polonia), Informe Académico de Gale Cengage Learning (México), Periódica de la Universidad Nacional Autónoma de México (México), Oceanet (España) y Dialnet de la Universidad de la Rioja (España). También hace parte de los siguientes directorios: Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, España y Portugal Latindex (México), Índice Bibliográfico Actualidad Iberoamericana (Chile), e-Revistas (España), DOAJ (Suecia), Ulrich de Proquest (Estados Unidos).

Tecnura es una revista arbitrada mediante un proceso de revisión entre pares de doble ciego. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

La Universidad Distrital Francisco José de Caldas, sus directivas, el Editor, el Comité Editorial y Científico no son responsables por la opinión y criterios expresados en el contenido de los artículos y estos se publican bajo la exclusiva responsabilidad de los autores y no necesariamente reflejan el pensamiento del Comité Editorial.

Además de la versión impresa, la revista Tecnura tiene también una versión digital disponible en su página web: http://revistas.udistrital.edu.co/ojs/index.php/Tecnura

TIPOS DE ARTÍCULOS ACEPTADOS

De acuerdo con la clasificación del Índice Nacional de Publicaciones Científicas y Tecnológicas

(Publindex-Colciencias), la revista Tecnura recibe postulaciones de artículos inéditos de los siguientes tipos:

Artículos de investigación científica y tecnológica: documento que presenta, de manera detallada, los resultados originales de proyectos de investigación. La estructura generalmente utilizada contiene cuatro apartes importantes: introducción, metodología, resultados y conclusiones.

Artículo de revisión: documento resultado de una investigación donde se analizan, sistematizan e integran los resultados de las investigaciones publicadas o no publicadas, sobre un campo en ciencia o tecnología, con el fin de dar cuenta de los avances y las tendencias de desarrollo. Se caracteriza por presentar una cuidadosa revisión bibliográfica de al menos 50 referencias.

FORMATO DEL ARTÍCULO

Del lenguaje y estilo apropiado para la redacción de artículos

- Deben emplearse estructuras de oraciones simples, evitando las que sean demasiado largas o complejas.

- El vocabulario empleado debe ser básico y común. Los términos técnicos deben explicarse brevemente; asimismo, el significado de las siglas debe presentarse la primera vez que estas aparecen en el texto.
- Los autores son responsables de que su trabajo sea conducido de una manera profesional y ética.

De la extensión de los documentos

Los artículos no deben tener una extensión de más de 25 páginas en tamaño carta y a doble espacio, con márgenes simétricas de 3 cm. Solo en el caso de los artículos de revisión las 25 páginas no inclu- yen las referencias bibliográficas.

Del formato de presentación

Los artículos presentados deben ser trabajos inédi- tos escritos en español o inglés y deben digitarse en Microsoft Word (2003 en adelante), cumplien- do con las siguientes indicaciones:

Letra *Times New Román* de 12 puntos (a excep- ción de que se requiera lo contrario para algunos apartados).

- Una columna a doble espacio.
- Todas las márgenes de 3 cm.
- Los párrafos se justifican, y no debe haber espacio entre los consecutivos.
- No incluir saltos de página o finales de sección.
- Si se desea resaltar palabras o frases del texto, no usar letra negrita sino letra cursiva.
- Los decimales se deben señalar con coma (,) y no con un punto.
- Los millares y millones se deben señalar con un espacio fino.
- Evitar las notas de pie de página.
- Se debe utilizar nomenclatura arábiga hasta el tercer nivel únicamente.

De la estructura del documento

Los trabajos deben tener la siguiente estructura y cumplir con los siguientes requisitos:

Composición de un artículo

Todos los artículos remitidos para su evaluación y posible publicación por parte de la revista Tecnura deben tener por lo menos los siguientes componentes:

- Título en español e inglés.
- Información de los autores.
- Resumen en español e inglés.
- Palabras clave en español e inglés.
- Introducción.
- Conclusiones.
- Trabajo futuro (opcional).
- Agradecimientos (opcional).
- Referencias bibliográficas.

Si el artículo es de investigación científica y tec- nológica deben tener, además de lo anterior, los siguientes componentes:

- Metodología.
- Resultados.
- Financiamiento.

Título

ítulo El título del artículo deberá ser corto o dividido en título y subtítulo, atractivo para el lector potencial y escrito en mayúscula sostenida. Este debe aparecer centrado entre las márgenes, escrito con letra *Times New Roman*, en negrita, tamaño de fuente 18. El título del artículo debe ir en español e inglés separado por un espacio doble. Máximo 20 palabras.

Autores

Después del título debe escribirse el (los) nombre(s) completo(s) del (los) autor(es), acompañado de los datos biográficos básicos: título de pregrado, título de posgrado, ocupación o cargo, afiliación institucional (institución donde labora), dependencia, ciudad, país y correo electrónico. La información anterior debe ir inmediatamente debajo del nombre del autor.

Resumen

Debe establecer el objetivo y alcance del trabajo, una descripción clara y concisa de la metodología, los resultados y las conclusiones obtenidas. Máximo 250 palabras.

Palabras clave

Debe escogerse entre tres y diez palabras clave, escritas en español con letra *Times New Roman*, en negrita y cursiva.

Las palabras clave deben estar escritas en orden alfabético y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos internacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar el tesauro de la UNESCO que se pueden encontrar en la página: http://databases.unesco.org/thessp.

Abstract

Debe ser una traducción correcta y precisa al idioma inglés del texto que aparece en el resumen en español.

Keywords

Debe ser una traducción correcta y precisa al idioma inglés de la lista de palabras clave en español.

Las *keywords* deben estar escritas en el orden de las palabras clave y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos in- ternacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar los Tesauros de la IEEE y/o World Bank que se pueden encontrar en las siguientes páginas respectivamente: http://www.ieee.org/documents/2009Taxonomy_v101.pdf, http://multites.net/mtsql/wb/site/default.asp

Introducción

Debe describir el planteamiento general del trabajo, así como contexto, antecedentes, estado de arte de la temática abordada, objetivo y posible alcance del trabajo.

Metodología

La redacción de este apartado debe permitir a cualquier profesional especializado en el tema replicar la investigación.

Resultados

Explicación e interpretación de los hallazgos. Si es necesario, se puede presentar una discusión breve y enfocada a la interpretación de los resultados.

Conclusiones

Implicación de los resultados y su relación con el objetivo propuesto.

Financiamiento

Mencionar la investigación asociada de la cual se derivó el artículo y la entidad que avaló y financió dicha investigación.

Agradecimientos

Preferiblemente deben ser breves y deben incluir los aportes esenciales para el desarrollo del trabajo.

Ecuaciones

Deben aparecer centradas con respecto al texto principal. Las ecuaciones deben ser referenciadas con números consecutivos (escritos entre paréntesis cerca al margen derecho). Las ecuaciones se citan en el texto principal empleando la palabra ecuación y seguida del número entre paréntesis. Las ecuaciones deben ser elaboradas en un editor de ecuaciones apropiado y compatible con el paquete de software InDesign, por ejemplo, el editor de ecuaciones de Windows.

Tablas

Para el caso de realización de tablas se recomienda que estas no sean insertadas como imágenes, considerando que en este formato no pueden ser modificadas. El encabezado de cada tabla debe incluir la palabra Tabla (en negrita) seguida del número consecutivo correspondiente y de un breve nombre de la tabla. El encabezado debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9.

No se presentan cuadros sino tablas y estas se deben levantar automáticamente desde el procesador de textos. Las tablas deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda tabla debe tener en su parte inferior la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Figuras

Todas las figuras o fotografías deben enviarse en formato PNG o TIFF con una resolución mínima de 300 DPI, adaptadas a escala de grises.

El pie o rótulo de cada figura debe incluir la palabra Figura (en negrita) seguida del número consecutivo correspondiente y de una breve descripción del contenido de la figura. El pie de figura debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9. Las figuras deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda figura debe tener también la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Símbolos

Los símbolos de las constantes, variables y funciones en letras latinas o griegas –incluidos en las ecuaciones– deben ir en cursiva; los símbolos matemáticos y los números no van en cursiva. Se deben identificar los símbolos inmediatamente después de la ecuación. Se deben utilizar las unidades, dimensiones y símbolos del sistema internacional.

Cuando se empleen siglas o abreviaturas, se debe anotar primero la equivalencia completa, seguida de la sigla o abreviatura correspondiente entre paréntesis y en lo subsecuente se escribe solo la sigla o abreviatura respectiva.

Referencias bibliográficas

El estilo de citación de referencias adoptado por la revista Tecnura es APA sexta edición. Las citas, referencias bibliográficas e infografía se incluyen al final del artículo. Las referencias bibliográficas deben ordenarse alfabéticamente de acuerdo con el primer apellido del primer autor, sin numeración.

Solo deben aparecer las referencias que fueron citadas en el texto principal del trabajo, en las tablas o en las figuras. Es decir, en la lista no deben aparecer otras referencias aunque hayan sido consultadas por los autores para la preparación del trabajo. Sugerimos utilizar herramientas como: *Citas y bibliografía de Microsoft Word* (para APA sexta edición versión 2013 o superior), *Zotero, Mendeley*, entre otras.

El llamado de una referencia bibliográfica se inserta en el texto, en el punto pertinente, bajo ciertas características:

- Si la oración incluye el apellido del autor, solo se debe escribir la fecha dentro de un paréntesis, ejemplo:

  Cuando Vasco (2012), analizó el problema de presentado en ....

- Cuando no se incluye el autor en la oración, debe ir entre el paréntesis el apellido y la fecha. La investigación de materiales dio una visión en el área (Martínez, 2012).

- Si el documento u obra tiene más de dos autores, se debe citar la primera vez con todos los apellidos. 1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) ....

- En las menciones siguientes, solo se debe escribir el primer apellido del autor, seguido de un "et al". En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que ...

- Cuando el documento u obra tiene más de seis autores, se debe utilizar desde la primera mención el "et al".

A continuación se describen una serie de ejemplos de las referencias más utilizadas, según el estilo de referencias adoptado por la revista Tecnura:

Publicaciones Periódicas:

Forma Básica

Apellidos, A. A., Apellidos, B. B. & Apellidos, C. C. (Fecha). Título del artículo. Título de la publicación, volumen (número), pp. xx-xx. doi: xx.xxxxxxx

Artículo básico

Guevara López, P., Valdez Martínez, J., Agudelo González, J., & Delgado Reyes, G. (2014). Aproximación numérica del modelo epidemiológico SI para la propagación de gusanos informáticos, simulación y análisis de su error. Revista Tecnura, 18(42), 12 -23. doi: http://dx.doi.org/10.14483/udistrital.jour.tecnura.2014.4.a01

Artículo web

Rodríguez Páez, S., Fajardo Jaimes, A., & Páez Rueda, C. (2014). Híbrido rat-race miniaturizado para la banda ISM 2,4 GHZ. Revista Tecnura, 18(42), 38-52. Recuperado de http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/article/view/8059/9675

Libros:

Forma Básica

Apellidos, A. A. (Año). Título. Ciudad: Editorial.

Apellidos, A. A. (Año). Título. Recuperado de http://www.xxxxxx.xxx

Apellidos, A. A. (Año). Título. doi: xx.xxxxxxxx

Apellidos, A. A. (Ed.). (Año). Título. Ciudad: Editorial.

Libro con autor

Goleman, D. (2000). La inteligencia emocional: Por qué es más importante que el cociente intelectual. México: Ediciones B.

Libro con editor

Castillo Ortiz, A. M. (Ed.). (2000). Administración educativa: Técnicas, estrategias y prácticas gerenciales. San Juan: Publicaciones Puertorriqueñas

Libro versión electrónica:

Montero, M. & Sonn, C. C. (Eds.). (2009). Psychology of Liberation: Theory and applications. [Versión de Springer]. doi: 10.1007/ 978-0-387-85784-8

Informe técnico

Forma Básica

Apellidos, A. A. (Año). Título. (Informe Núm. xxx). Ciudad: Editorial

Informe con autores

Weaver, P. L., & Schwagerl, J. J. (2009). U. S. Fish and Wildlife Service refuges and other nearby reserves in Southwestern Puerto Rico. (General Technical Report IITF-40). San Juan: International Institute of Tropical Forestry.

Informe de una agencia del gobierno

Federal Interagency Forum on Child and Family Statistics. America's Children: Key National Indicators of Well-Being, 2009. Washington, DC: U.S. Government Printing Office. Recuperado de http://www.childstats.gov/pubs/index.asp

Tesis

Forma Básica

Apellidos, A. A. (Año). Título. (Tesis inédita de maestría o doctorado). Nombre de la institución, Localización.

Tesis inédita, impresa

Muñoz Castillo, L. (2004). *Determinación del conocimiento sobre inteligencia emocional que poseen los maestros y la importancia que le adscriben al concepto en el aprovechamiento de los estudiantes*. (Tesis inédita de maestría). Universidad Metropolitana, San Juan, PR.

Tesis de base de datos comercial

Santini Rivera, M. (1998). *The effects of various types of verbal feedback on the performance of selected motor development skills of adolescent males with Down syndrome*. (Tesis doctoral). Disponible en la base de datos ProQuest Dissertations and Theses. (AAT 9832765).

Tesis web

Aquino Ríos, A. (2008). *Análisis en el desarrollo de los temas transversales en los currículos de es- pañol, matemáticas, ciencias y estudios sociales del Departamento de Educación.* (Tesis de maestría, Universidad Metropolitana). Recuperado de http://suagm.edu/umet/biblioteca/UMTESIS/Tesis_Educacion/ARAquinoRios1512.pdf

Estándares o patentes

Forma Básica

Apellidos, A. A. Título de la patente. País y número de la patente. Clasificación de la patente, fecha de concesión oficial. Número y fecha de solicitud de la patente, paginación.

Hernández Suárez, C. A., Gómez Saavedra, V. A., & Peña Lote, R. A. Equipo medidor de indica-

dores de calidad del servicio de energía eléctrica para usuario residencial. Colombia., 655. G4F 10/0, 15 de Marzo 2013. 27 de Octubre 2011, 147

ENVÍO DE ARTÍCULOS

Los autores deben enviar sus artículos a través de la aplicación para tal fin del Open Journal System en formato digital, adjuntando la carta de presentación y el formato de información artículo-autores.

Carta de presentación

El artículo debe ir acompañado de una carta de presentación dirigida al director y editor de la revista, Ing. Cesar Augusto García Ubaque, donde incluya:

- Solicitud expresa de considerar su artículo para publicarlo en la revista Tecnura.
- Título completo del trabajo.
- Nombres completos de todos los autores del trabajo.
- Certificación de la originalidad y el carácter inédito del trabajo.
- Exclusividad de su remisión a la revista Tecnura.
- Confirmación de la autoría con la firma de todos los autores.

Esta carta deberá estar firmada por todos los autores, escanearse y enviarse junto con los demás documentos solicitados.

Formato de información artículo-autores

El artículo además debe ir acompañado de un formato de información sobre el artículo y sus autores, el cual se puede descargar de la página web de la revista Tecnura: `http://revistas.udistrital.edu.co/ojs/index.php/Tecnura`, en la sección "Formatos y Documentos". Es importante completar todos los campos de información solicitados, algunos de ellos tienen comentarios para aclarar mejor lo que se está solicitando. El formato no debe escanearse.

Artículo

Artículo en formato digital (Word 2003 en adelante) que cumpla con todas las normas de presentación descritas en el capítulo 3, "Formato del artículo", de la presente en las instrucciones a los autores.

PROCEDIMIENTO PARA LA PUBLICACIÓN

El procedimiento que sigue la revista Tecnura para la evaluación y posible publicación de los trabajos enviados por los autores es el siguiente en orden cronológico:

1. Envío del articulo acompañado de la carta de presentación y el formato de información por parte de los autores.
2. Notificación al autor de correspondencia de la recepción del artículo.
3. Verificación del tema del artículo con respecto a las áreas de interés de la revista.
4. Verificación de las normas de presentación por parte del monitor de la revista.
5. Notificación al autor de correspondencia de la evaluación de las normas de presentación.
6. Envío de las correcciones realizadas por los autores con respecto a la evaluación de las normas de presentación
7. Envío del artículo a los árbitros seleccionados.
8. Notificación del inicio del proceso de arbitraje del artículo.
9. Notificación a los autores de la decisión tomada por el Comité Editorial y de las evaluaciones hechas por los árbitros.
10. Envío de las correcciones realizadas por los autores con respecto a las evaluaciones de los árbitros.
11. Estudio de la versión final del artículo y de las evaluaciones de los árbitros por parte del Comité Editorial.
12. Envío por parte de los autores de la carta de cesión de derechos al editor de la revista.
13. Envío de la versión con corrección de estilo y diagramada a los autores.
14. Verificación de errores y aprobación final de la versión con corrección de estilo y diagramada por parte de los autores.
15. Publicación del artículo en el número correspondiente de la revista Tecnura.
16. Notificación a los autores de la publicación del número de interés.
17. Envío de un ejemplar de la revista a cada autor del artículo publicado.

PROCESO DE ARBITRAJE DE ARTÍCULOS

Considerando la periodicidad trimestral de la revista, el Comité Editorial realiza cuatro convocatorias anuales para la recepción de artículos, aproximadamente en los meses de febrero, mayo, agosto y noviembre. Los artículos serán recibidos hasta la fecha máxima establecida en cada convocatoria.

Una vez recibidos los artículos el monitor de la revista realizará una primera evaluación de forma para verificar que cumplan con todos los elementos mencionados en esta guía de instrucciones a

los autores. Luego de recibir nuevamente el articulo con las correcciones de forma solicitadas por el monitor de la revista, este será sometido a evaluación por tres pares académicos (paulatinamente se espera incorporar un mayor número de pares externos que participen en el proceso).

Cada artículo remitido a la revista Tecnura es revisado por dos pares académicos externos a la institución de los autores, mediante un proceso de "revisión entre pares" (*Peer-review*) de doble-ciego, garantizando el anonimato de los autores y evaluadores; se considera confidencial todo trabajo recibido y así se le exige a sus evaluadores.

Las posibles conclusiones de los resultados de la evaluación por parte de los árbitros son únicamente tres: publicar el artículo sin modificaciones, publicar el artículo con modificaciones o no publicar el artículo.

Posteriormente, el Comité Editorial toma la decisión de publicar o no los artículos, con base en los resultados de las evaluaciones realizadas por los árbitros asignados. En caso de existir contradicciones en las evaluaciones con respecto a la publicación de un artículo, el Comité Editorial enviará el artículo a un tercer árbitro y se inclinará por las dos evaluaciones que tengan el mismo concepto respecto a la publicación del artículo.

En cada convocatoria el autor de correspondencia debe sugerir al menos cuatro posibles evaluadores externos a su institución laboral, los cuales deben ser especialistas en el tema específico del artículo remitido, tener al menos maestría y por lo menos dos deben ser internacionales. Los posibles evaluadores pueden pertenecer a una universidad o industria, pública o privada; de estos se debe proporcionar el nombre completo, su formación académica más alta, su afiliación institucional y su correo electrónico. Estos cuatro potenciales evaluadores serán analizados por el Comité Editorial a fin de ampliar la base de datos de los árbitros de la revista Tecnura.

El Comité Editorial de la revista Tecnura se reserva los derechos de impresión, reproducción total o parcial del artículo, así como el de aceptarlo o rechazarlo. Igualmente, se reserva el derecho de hacer cualquier modificación editorial que estime conveniente; en tal caso el autor recibirá por escrito recomendaciones de los evaluadores. Si las acepta, deberá entregar el artículo con los ajustes sugeridos dentro de las fechas fijadas por la revista para garantizar su publicación dentro del número programado.

CONTACTO

Para cualquier solicitud de información adicional puede comunicarse a través del correo electrónico de la revista Tecnura: tecnura@udistrital.edu.co, tecnura@gmail.com, o por mensajería con el Ing. Cesar Augusto García Ubaque, Director y Editor de la revista Tecnura, a la dirección:

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