

T e k h n ê

Tecnología al servicio de la sociedad

Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

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• Superior derecha: Sensing, position estimation and motion (Martínez, F.)

• Centro: Characteristic behaviors of reflected traveling waves.
a) waveform for a fault at 50 km, b) waveform for a fault at 30 km, c) waveform for a fault at 10 km and d) waveform for a fault at 100 km (Ochoa, Y., y Penagos, C.)

• Inferior izquierda: Loading 35 robots in a simulation (Rodríguez, E., y Romero, D.)

• Inferior derecha: Results screen (Rodríguez, E., y Romero, D.)

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La revista **Tekhnê** es una publicación institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas. Posee un carácter científico, y atiende a la comunidad nacional e internacional especialista en áreas de ingenierías eléctrica, electrónica, mecánica, de sistemas, industrial y civil. Publica resultados de investigación en inglés (artículos originales e inéditos), y está completamente abierta a especialistas de todo el mundo en calidad de autores y/o lectores. Es arbitrada mediante un proceso doble ciego, con rotación continua de árbitros. 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

La revista **Tekhnê** posee una periodicidad semestral, coincidente con los semestres académicos de la Universidad Distrital. La publicación se realiza los meses de julio y diciembre. El primer volumen de la revista se publicó el primer semestre de 2003, manteniendo su regularidad hasta la fecha.

Misión

La revista **Tekhnê** tiene como misión divulgar resultados 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. Propende por la difusión de resultados y su acceso abierto y libre.

Público objetivo

La revista está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científica en el campo de la ingeniería.

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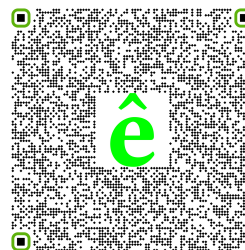
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• Lower right: Results screen (Rodríguez, E., and Romero, D.)

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Tekhnê Journal

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Periodicity

Tekhnê journal is published every six months, coinciding with the academic semesters of the Universidad Distrital. It is published in July and December. The first volume of the journal was published in the first semester of 2003, maintaining its regularity to date.

Mission

The mission of **Tekhnê** journal is to disseminate research results conducted in the area of engineering, through the publication of original and unpublished articles by academics and professionals belonging to national or foreign institutions of public or private order. It aims at the diffusion of results and their open and free access.

Target audience

The journal is aimed at professors, researchers, students, and professionals interested in permanently updating their knowledge and monitoring scientific research processes in the field of engineering.

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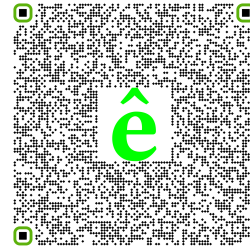
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Declaración de ética y buenas prácticas

Tekhnê

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Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

Revista Tekhnê
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El comité editorial de la revista **Tekhnê** 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:

Obligaciones y responsabilidades generales del equipo editorial

En su calidad de máximos responsables de la revista, el comité y el equipo editorial de **Tekhnê** 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.

Relaciones con los autores

Tekhnê 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 confluían graves circunstancias.

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Tekhnê 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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Tekhnê se compromete responder con rapidez a las quejas recibidas y a velar para que los demandantes insatisfechos puedan tramitar todas sus quejas. En cualquier caso, si los interesados no consiguen satisfacer sus reclamaciones, se considera que están en su derecho de elevar sus protestas a otras instancias.

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Tekhnê 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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Integridad y rigor académico

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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La relación entre editores, editoriales y propietarios estará sujeta al principio de independencia editorial. **Tekhnê** garantizará siempre que los artículos se publiquen con base en su calidad e idoneidad para los lectores, y no con vistas a un beneficio económico o político. En este sentido, el hecho de que la revista no se rija por intereses económicos, y defienda el ideal de libre acceso al conocimiento universal y gratuito, facilita dicha independencia.

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

Quejas/denuncias

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

Code of ethics and good practice

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Tekhnê Journal
Universidad Distrital Francisco José de Caldas
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The editorial board of **Tekhnê** 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, **Tekhnê** 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 the research and their role in the research.

Relations with authors

Tekhnê 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.

Relations with evaluators

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

Peer review process

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

Claims

Tekhnê 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

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

Protection of individual data

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

Tracking malpractice

Tekhnê 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.

Integrity and academic rigour

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.

Relations with owners and journal editors

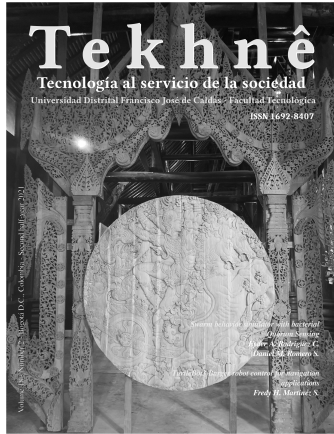
The relation between editors, publishers and owners will be subject to the principle of editorial independence. **Tekhnê** will ensure that articles are published based on their quality and suitability for readers, and not for an economic or political gain. In this sense, the fact that the journal is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

Conflict of interest

Tekhnê will establish the necessary mechanisms to avoid or resolve potential conflicts of interest between authors, reviewers and/or the editorial board itself.

Complaints/allegations

Any author, reader, reviewer or editor may refer their complaints to the competent authorities.



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Editorial

*P*oco a poco las universidades colombianas regresan a su antigua presencialidad. A causa de la pandemia del COVID-19 y el confinamiento obligatorio establecido por el gobierno nacional, las entidades de educación del país habían optado por una estrategia de formación a distancia soportada por conexiones de videoconferencia y plataformas MOOC (cursos masivos abiertos en línea) sobre Internet como alternativa mientras se manejaba la situación sanitaria del país. En los últimos meses, se ha extendido la vacunación a nivel mundial, lo que ha controlado la dispersión del virus, permitiendo que muchos gobiernos, entre ellos el colombiano, establecieran normas de regreso gradual a los espacios físicos de formación.

Aun así, hay muchas dudas en relación con este regreso. Si bien muchos padres de familia apoyan esta estrategia, en ciertos casos presionados por sus hijos solos en casa y problemas de comportamiento y conducta al interior de sus hogares, muchos otros mantienen su preocupación por la mortalidad del virus, y las pocas garantías que ofrecen ciertas instituciones, particularmente las públicas. En este sentido, es necesario mostrar a la comunidad que la sanidad y la salud de la población es una prioridad frente a otros derechos sociales, y que realmente existen las condiciones de regreso a la presencialidad, no únicamente al interior de las instituciones, sino en todos los espacios públicos, particularmente en el transporte.

Es un gran alivio que esta etapa que vivimos, causada por el virus, empiece a tener luz al final del túnel. Se habla de una nueva normalidad en la cual las máscaras quirúrgicas talvez se resistan a desaparecer dadas las ventajas que se han aprendido de ellas, como lo es la reducción significativa de las enfermedades respiratorias en general. Talvez esta nueva normalidad de luz a una sociedad más inteligente y preparada, que logre afrontar con mayor sabiduría los nuevos retos del futuro.

Prof. Fredy H. Martínez S., Ph.D

Docente Facultad Tecnológica
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Editorial

*L*ittle by little, Colombian universities are returning to their former face-to-face presence. Because of the COVID-19 pandemic and the mandatory confinement established by the national government, the country's educational entities had opted for a distance learning strategy supported by video conferencing connections and MOOC (massive open online courses) platforms over the Internet as an alternative while the country's health situation was being managed. In recent months, vaccination has been extended worldwide, which has controlled the spread of the virus, allowing many governments, including the Colombian government, to establish rules for a gradual return to physical learning spaces.

Even so, there are many doubts regarding this return. While many parents support this strategy, in certain cases pressured by their children alone at home and behavioral and conduct problems within their homes, many others remain concerned about the mortality of the virus, and the few guarantees offered by certain institutions, particularly public ones. In this sense, it is necessary to show the community that the sanitation and health of the population is a priority compared to other social rights and that there really are conditions for a return to the presence, not only within institutions but in all public spaces, particularly in transportation.

It is a great relief that this stage we are going through, caused by the virus, is beginning to have light at the end of the tunnel. There is talk of new normality in which surgical masks may resist disappearing given the advantages that have been learned from them, such as the significant reduction of respiratory diseases in general. Perhaps this new normality will give light to a more intelligent and prepared society, which will be able to face the new challenges of the future with greater wisdom.

Prof. Fredy H. Martínez S., Ph.D

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Traveling wave method for analysis of faults in a high voltage transmission line

Método de las ondas viajeras para el análisis de fallas en una línea de transmisión de alta tensión

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This paper presents an analysis of the error presented in the location of faults by the traveling wave method, and the traveling wave method analyzing reflected waves. This analysis arises from the results of the simulation of a high voltage transmission line in the ATP-EMTP software that allows us to simulate faults in a very graphical way and gives, as a result, the waveform presented at the measurement points. The results show similar behavior between theoretical behavior and simulation.

Keywords: ATP-EMTP, fault location, high voltage, transmission line, traveling wave

En este artículo se presenta un análisis sobre el error presentado en la ubicación de fallas por el método de ondas viajeras, y el método de ondas viajeras analizando ondas reflejadas. Este análisis surge de los resultados de la simulación de una línea de transmisión en alta tensión en el software ATP-EMTP que nos permite simular fallas de una forma bastante gráfica, y da como resultado la forma de onda presentada en los puntos de medición. Los resultados muestran comportamientos similares entre comportamiento teórico y simulación.

Palabras clave: Alta tensión, ATP-EMTP, línea de transmisión, localización de fallas, onda viajera

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Introduction

Nowadays, one of the main drawbacks of power systems is when a fault occurs (Li et al., 2020; Saber et al., 2020). Whether its source is natural, or due to bad execution of work in the power system, these failures cause supply problems (Afrasiabi et al., 2020; Ren et al., 2020). One of the most worrying faults is those that occur in the lines, whether transmission or distribution, since the exact location of the fault is not known (Wang & Dehghanian, 2020). The entire section of the line to find it could take a long time, making the service inefficient. To estimate the place of occurrence of the fault there are a variety of methods that reduce the search space, and therefore maintenance costs. To mention some of these methods we have the application of the differential principle in the traveling wave method to determine the locations of faults in overhead lines with branches using the navigation approach (Barman & Hazarika, 2020; Gafoor & Rao, 2006). The least-squares method is used to determine the wave propagation velocity.

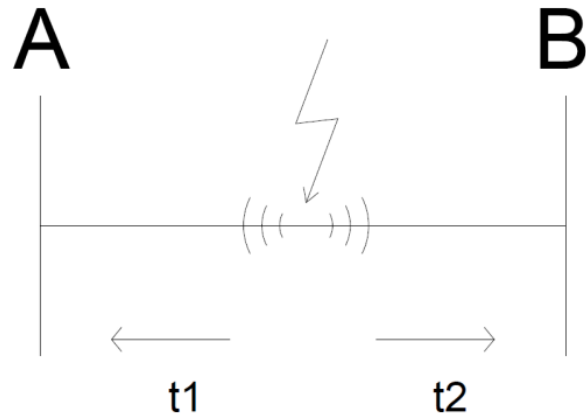
Another interesting method for estimating the location of a fault in the network is based on traveling wave analysis. The main advantage of this strategy is that it does not require the use of GPS global positioning systems for the synchronization of the system. In this case, to extract the transient wavelet from the wavelets recorded on the bus bars, wavelet elimination using the Wavelet transform is used (Abubakar et al., 2020; Cherif et al., 2020). The residual signal in this procedure has a large amount of information about the fault. The algorithm uses the statistical analysis parameters of the traveling wavelet as the input to a categorization system, which in our case is an artificial neural network (Rafique et al., 2021).

In this study, to perform fault studies on the different types of faults, and the performance of each strategy, type faults are generated using the ATP-EMTP software tool (Adly et al., 2020; Torres et al., 2020). The results obtained for each case are then categorized and discussed. The proposed network has a reliable response, an average error of 0.92% shows the power of the algorithm against the one based on reactance techniques. In contrast, this is a higher error than that obtained with the traveling wave-based fault location strategy, which uses GPS synchronization.

Regardless of the strategy used to estimate the location, the fault location method is costly because the measurement is associated with the value of the equipment to be used (Huang et al., 2020; Rivas & Abrão, 2020). This is because it is required to quantify fairly small time differences, and therefore, the equipment must have quite demanding accuracy characteristics. However, the benefits of locating a fault on a major transmission line outweigh this value (Yousaf et al., 2020).

Figure 1

Traveling waves produced on a fault.



Fault location principles

Traveling waves

This strategy is based on electromagnetic pulses of current and voltage signals with very high frequencies that are produced by a transmission line fault. These disturbances can occur due to atmospheric phenomena, connection, or disconnection maneuvers of the equipment, such waves propagate in both directions of the line from the fault (Fig. 1).

The propagation speed of this wave is the speed of light, i.e. 300,000 km/s. Thus, with a simple calculation, taking the time difference in which this wave arrives at the ends of the line, it is possible to calculate the distance at which the fault is located (Eq. 1).

$$d = \frac{L - v(t_2 - t_1)}{2} \quad (1)$$

Where:

- d = distance of the fault from node 1 [km].
- L = total length of the line [km].
- v = speed of light = 300,000 [km/s].
- t_2 = wave arrival time at node B [s].
- t_1 = wave arrival time at node A [s].

For the application and execution of the procedure of this method, quite precise equipment is required, since a variable such as speed, its precise measurement requires precise and quality equipment, and therefore expensive.

Reflected traveling waves

The analysis of the traveling waves is complemented with the analysis of the reflected traveling waves, which shows how the reflection of the wave, an event that occurs at each node and the point of the fault, allows a redundant calculation to be made, since by using the reflection and refraction of the wave in the case of the point of the fault, a second distance calculation can be made, calculating the time it takes to travel the distance of the fault again.

Fig. 2 shows different waveforms corresponding to faults at different distances from node A (red wave) and node B (green wave). Thus we see that in signal (a) corresponding to a 50 km fault on a 200 km line, the traveling wave between the fault point and node A is reflected a couple of times before the fault is detected by node B. On the other hand in waveform (b) corresponding to a fault 30 km from node A, the wave is reflected between the fault and the node a total of 7 times. Waveform (c) corresponds to a fault very close to the study node, the wave is reflected many times in very small times compared to the two previous examples. Finally, the waveform (d) simulates a fault distance that corresponds to half of the line, being easy to notice that the times in which the waves and their reflections and refractions are the same in both nodes.

To record the times we can resort to the Lattice time-space diagram, where the movement of the reflected and transmitted waves are represented at any time, this diagram has the following considerations (Eq. 2).

- All waves start in a positive direction from left to right.
- The potential at any instant of time is the superposition of all the waves from which they arrive at the point until the instant of time, displaced in the position of each one by time intervals, is equal to the time difference of their arrival.
- The test values change in 10 km sections starting at node A and in the direction of the node, thus allowing a stepwise analysis of the results.
- The percentage error of the calculated distance concerning the actual distance calculated with the following equation is presented.

$$Error [\%] = \frac{\text{Calculated Distance} - \text{Actual Distance}}{\text{Total Line Length}} \quad (2)$$

Methods

The study proposes a simple structure, where the methods selected at the beginning will be explained and an analysis of their use, advantages, and disadvantages will be made. A simple transmission line and two substations at the ends

are used. For the ATP simulation, it will be simulated as if it were two lines of different lengths, and the fault will be simulated at the junction of these two. Signals are recorded to detect the variables necessary to perform the calculation by the traveling wave method.

These simulations will be performed with the fault in different sections of the line, thus changing the distance to be detected as a result. With the real distance, which would be the one entered in the line parameters, and the calculated distance, a percentage error calculation will be performed, which will be compared with other methods at the end.

A more complete version of this method will also be performed, which consists of adding the analysis with the reflected wave, a method that in theory gives better results. The different simulated faults will be performed with the element called *splinter* in the simulator, which serves to divide the three-phase scheme into three single-phase connections, thus allowing to simulate of a large number of faults. It will be possible to simulate single-phase ground fault, single-phase fault with impedance to ground, two-phase line-to-line fault, and two-phase line-to-ground fault.

Results

The transmission line is simulated with a length of 200 km with two generators at each end, with voltage at nodes A and Bus 2 of 230 kV. For the simulation of the fault, this section is divided with the element called *splinter* which serves to divide the three-phase scheme into three single-phase connections and thus make ground connections through timed switches, the design of the fault is presented with two lines in both directions which have the same model and occupy length values that together equal the 200 km.

The data resulting from the test are summarized in Table 1. The last column shows the comparative error compared to the theoretical values.

The average error for this method where no reflected wave analysis is performed is 0.2833%, thus demonstrating that it provides fairly accurate values considering the importance of the fault location in a real case.

Conclusion

When applying the method it can be observed that as the distance of the fault is greater the error decreases considerably, having an initial error of 0.5% and reaching an error of 0.025%, which suggests that the method is not accurate in short distances. Since the propagation speed of the wave corresponds to the speed of light, it can be deduced that the times measured by this method will be the same for any type of fault, a fact that was verified at the time of performing the simulation, which does not indicate that the method is indifferent to the type of fault and gives us the location of this regardless of its nature.

Figure 2

Characteristic behaviors of reflected traveling waves. a) waveform for a fault at 50 km, b) waveform for a fault at 30 km, c) waveform for a fault at 10 km and d) waveform for a fault at 100 km.

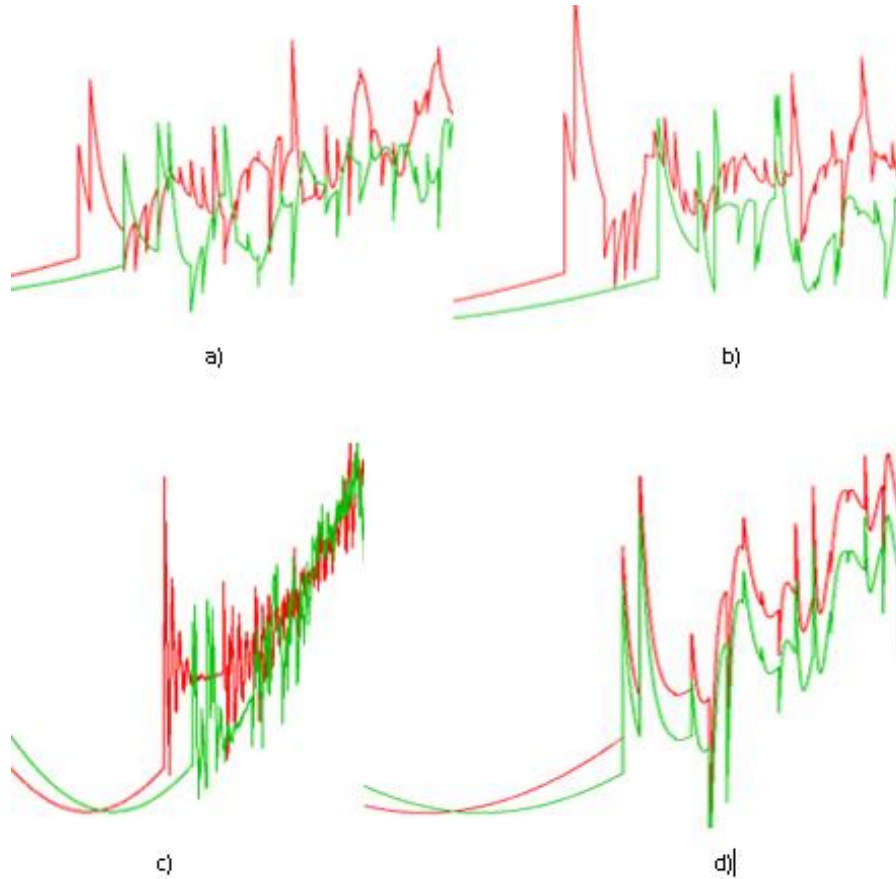


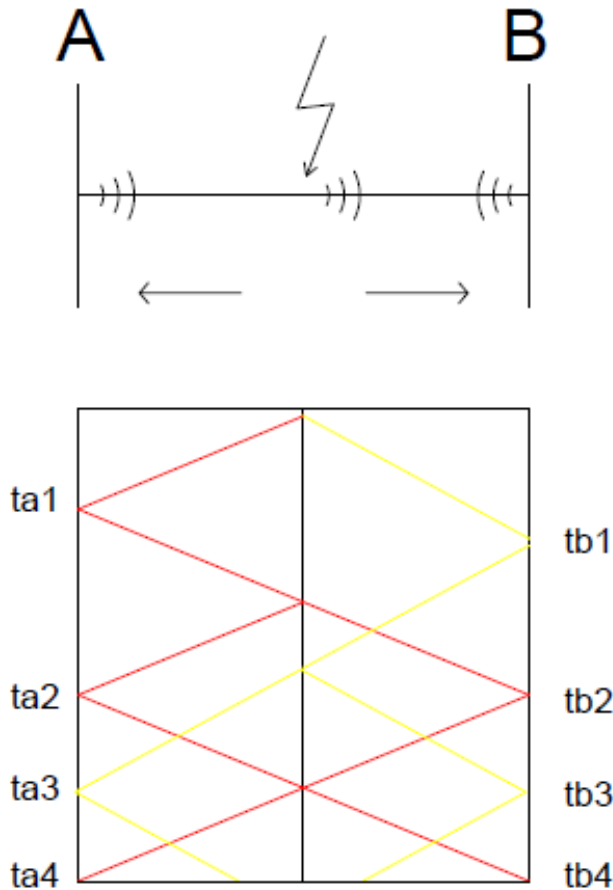
Table 1

Test data summary

Actual distance [km]	Measured time in A [s]	Measured time in B [s]	Calculated distance [km]	Error [%]
10	0.010034	0.010641	8.95	0.525
20	0.010068	0.010607	19.15	0.425
30	0.010101	0.010573	29.20	0.400
40	0.010135	0.010540	39.25	0.375
50	0.010169	0.010506	49.45	0.275
60	0.010202	0.010472	59.50	0.250
70	0.010236	0.010438	69.70	0.150
80	0.010270	0.010405	79.75	0.125
90	0.010304	0.010371	89.95	0.025
100	0.010337	0.010337	100.00	0.000

Figure 3

Traveling waves, fault model.



At the time of making the simulation, it was found that the equation with which distance is calculated gives us data very similar to the theoretical ones, it can also be said that the ATP program is a program that has many tools that help us to solve this type of problems, despite being free software, if it has some difficulties, it lacks aids, but for the same reason of being free to use.

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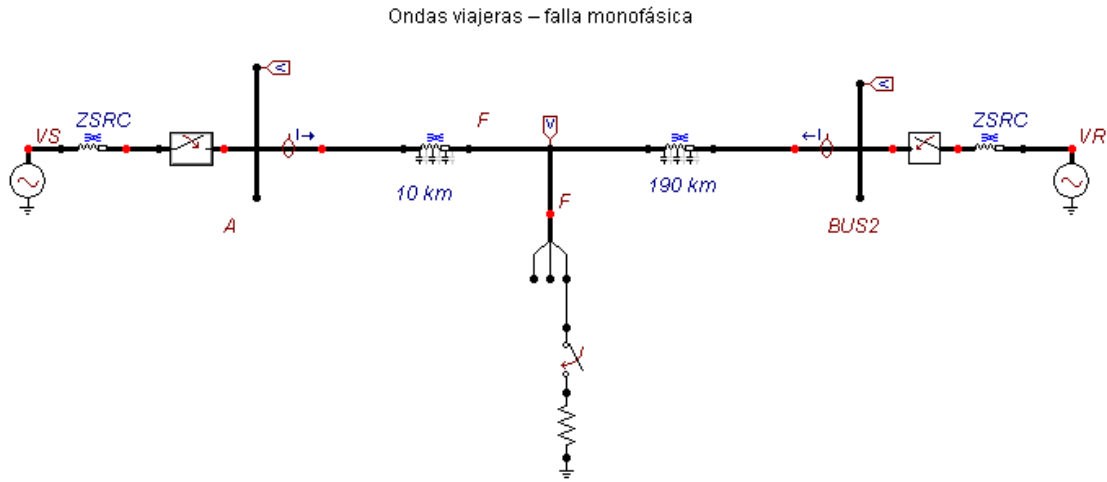
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Figure 4

Traveling waves, single-phase fault.



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TurtleBot3 robot operation for navigation applications using ROS

Manejo del robot TurtleBot3 para aplicaciones de navegación mediante ROS

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Logo is a programming language that was born in 1967 as a tool for learning programming. Its concept was simple, assign commands to a virtual turtle to trigger its movement. TurtleBot is a robotics research platform with development based on this concept. However, this platform is both hardware and software oriented and is widely accepted internationally, particularly in SLAM (Simultaneous Localization And Mapping), navigation, and manipulation applications. In fact, it is the standard ROS (Robot Operating System) platform. This paper aims to show the handling and programming of this robot for navigation applications using ROS and Python.

Keywords: Learning, navigation, research, robotics, ROS, TurtleBot3

Logo es un lenguaje de programación que nació en 1967 como herramienta para de aprendizaje en programación. Su concepto era simple, asignar órdenes a una tortuga virtual a fin de provocar su movimiento. TurtleBot es una plataforma de investigación robótica con desarrollo basado en este concepto. Sin embargo, esta plataforma está orientada tanto al hardware como al software, y posee gran aceptación a nivel internacional, particularmente en aplicaciones de SLAM (Simultaneous Localization And Mapping), navegación y manipulación. De hecho, es la plataforma estándar de ROS (Robot Operating System). Este documento pretende mostrar el manejo y programación de este robot para aplicaciones de navegación con el uso de ROS y Python.

Palabras clave: Aprendizaje, investigación, navegación, robótica, ROS, TurtleBot3

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Introduction

ROS (Robot Operating System) is a framework for study and research in robotics (Lentin, 2018; Moreno & Páez, 2017). The tool was developed in 2007 by the Stanford Artificial Intelligence Lab and is currently being developed and maintained by the Willow Garage with support from a broad group of institutions (Koubaa, 2020). As its name suggests, ROS provides standard services, just as an operating system does, related to hardware abstraction, low-level device control, implementation of commonly-used functionality, inter-process message passing, and package maintenance (Quigley et al., 2009). It is designed for UNIX systems, under BSD licensing terms, so it is widely used in Linux distributions such as Ubuntu, Fedora, and Arch, but it is also used in Mac OS X. The current version is called Melodic Morenia, which was released in 2018 and is supported until May 30, 2023.

TurtleBot is the standard ROS platform, and is the most popular hardware in research, particularly in motion planning strategies. The first prototype, TurtleBot1, was developed in 2010 from the development version of iRobot's Roomba. The second generation, TurtleBot2, was born two years later, in 2012 from the iCleo Kobuki platform (Hou et al., 2020; Poza-Lujan et al., 2019). In 2017 appears the current version, TurtleBot3, which solves the shortcomings of the previous versions and, like the previous versions, maintain full support with ROS (Groß, 2021).

The TurtleBot3 robot has great advantages for use in robotics, both in specific training and research (Al-Mashhadani et al., 2020; Fernandes et al., 2019). It is an affordable platform, widely used in research centers around the world, small and easy to adapt to specific needs, programmable in MatLab and Python, and as mentioned, fully compatible with ROS. Its small size does not sacrifice capability and performance but allows a highly competitive platform to be obtained with a small investment. Thanks to its 360-degree LiDAR (Light Detection And Ranging) sensor, this robot is a perfect choice for traditional SLAM applications in motion planning (Aslan et al., 2021; Ratul et al., 2021).

Work environment

Hardware overview

There are currently two versions of TurtleBot robots, which although quite similar, have some key differences between them. These are the Burger and Waffle models, the differences can be summarized in Table 1.

The Waffle model is slightly faster in forwarding motion and has a higher load capacity. However, it is much slower in turning, much larger has an additional camera, and is also considerably more expensive. For this reason, the research group opted for the Burger platform from which it acquired a

couple of robots. The camera may be useful in our research, but it can be integrated into the Burger platform at a later date.

The most important hardware components of the TurtleBot3 Burger robot are:

- **LiDAR sensor:** The robot uses a 360-degree LDS-01 LiDAR sensor. It is a laser scanner capable of collecting distance data around the robot with a range of 120 mm to 3,500 mm, an angular resolution of 1 degree, with a sampling rate of 1.8 kHz; and allows USB connection for computer and UART for embedded systems. It is located on the top of the robot.
- **Raspberry Pi development board:** The robot uses a Raspberry Pi 3 Model B development board that is located one level below the LiDAR sensor. Although it does not have large processing power, it is key to implement autonomous algorithms in the robot related to machine learning and digital image processing taking advantage of the ability to connect directly with sensors and actuators.
- **OpenCR (Open-source Control Module for ROS) hardware control board:** This board was developed to support ROS embedded systems, and is located one level below the Raspberry Pi board. It is implemented around the STM32F7 microcontroller from STMicroelectronics which has an ARM Cortex-M7 core with floating point unit. Development can be done with Arduino IDE and Scratch as well as traditionally with firmware. The board contains an inertial measurement unit (IMU) with a three-axis accelerometer, a gyroscope and a magnetometer, and allows connecting the Raspberry Pi to motors and sensors.
- **Additional elements.** Other important elements to consider in the robot include the motors and the 11.1 V lithium-polymer (LiPo) battery. It is a differential platform with two independent Dynamixel XL430-W250 motors on each wheel.

Robot Operating System (ROS)

ROS is really a meta-operating system, that is, although it is an operating system for robotics, it runs on top of another operating system (a UNIX system). The advantage of being an operating system for robots is that it allows supervising different parts of the robot (control boards, sensors, and actuators) regardless of the programming language that each of them uses in its implementation.

The structure of ROS is characterized by a file system in which an executable file makes up a node. One node can instruct a sensor to watch for a specific event, while another

Table 1

Differences between TurtleBot robot models

	Burger	Waffle
Maximum translational velocity	0.22 m/s	0.26 m/s
Maximum rotational velocity	2.84 rad/s (162.72 deg/s)	1.82 rad/s (104.27 deg/s)
Maximum payload	15 kg	30 kg
Size (L × W × H)	138 mm × 178 mm × 192 mm	281 mm × 306 mm × 141 mm
Weight	1.0 kg	1.8 kg

node can specify the movement of an actuator in response to this specific event. The two nodes in this case communicate with each other via message files. A message file can be of different types: topics, services, and actions, and they are grouped with the nodes to work together in a package folder. When this group of nodes is executed, the ROS master server takes on the task of messenger between the nodes, i.e., the node first sends the message to the master, which communicates the message to the receiving node.

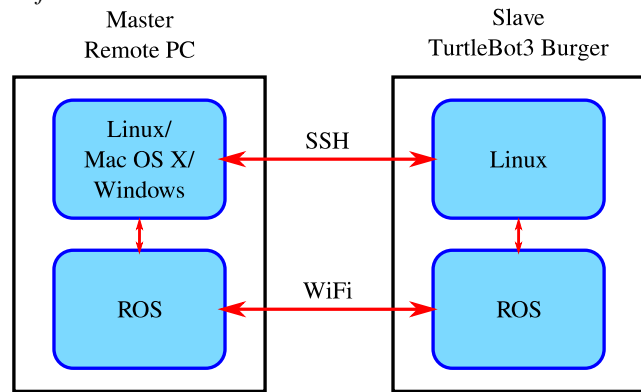
Software overview

The Raspberry Pi board requires an operating system adapted to its processor. Normally a Linux distribution is selected because of its development advantages and low cost. In the laboratory experiments carried out in this research, we used Ubuntu MATE 16.04 because of the extensive documentation, libraries, and repositories. As usual, this distribution was modified by the research group to suit the needs of the project.

The Raspberry Pi of each robot (and the computers of the research group) is connected to a central wireless access point (AP). This scheme facilitates the configuration of the algorithm, as well as the conceptualization of the algorithm architecture in multi-agent schemes. However, it is not the recommended working strategy when working with more than five robots since it presents a large latency in the communication that hinders the behavior of the algorithms. A change to the proposed working scheme for future implementations of swarm algorithms is to configure the Raspberry Pi board of each robot as an AP. During the tests with the multi-agent algorithms, there were connection problems due to the number of devices connected to the router, even though only two robots were used as maximum in the tests. Allowing the robots to have their own AP with fixed IP decreases the network load, avoiding communication problems. This also changes the implementation strategy of the algorithms, which is why it was not done at this stage of the project but is raised as a necessity for future work.

Figure 1

Software architecture.



To reduce the processing and memory requirements of the Raspberry Pi we removed unnecessary software included by default in the Linux distribution (office software and some system tools). Also, the graphical interface and libraries for handling peripherals such as printers were removed. ROS was installed in this tweaked version of Linux as well as important development tools in our algorithms such as Python and OpenCV. Although the master computer used in this research is also a Linux machine (MX Linux 21 Wildflower 64 bits with Kernel 5.10), it is also possible to use Windows OS servers (Fig. 1).

TurtleBot3 Burger control

The control code presented here was developed in Python for the kinematics of the TurtleBot3 Burger robot and assumes that ROS is installed on both the server computer and the robot’s Raspberry Pi. Detailed information can be found on the website of ROBOTIS, the robot’s manufacturer.

<https://emanual.robotis.com/docs/en/platform/turtlebot3/overview/>

The detailed model of this robot can be found in this paper (Lee et al., 2000).

Figure 2

Libraries.

```
#!/usr/bin/env python
import rospy
from geometry_msgs.msg import Twist
from nav_msgs.msg import Odometry
from math import pow, atan2, sqrt, sin, cos
from tf.transformations import euler_from_quaternion
import numpy as np
```

Code breaking down

The first block of code corresponds to the libraries used in the node. Each node in ROS carries the

```
#!/usr/bin/env python
```

declaration at the top, this ensures that the code is executed as a Python script. ROS messages must be imported for use as any Python library. The first library imported is `Twist` from `geometry_msgs.msg`, which allows controlling the movement of the robot, for which a message is published with two variables, the amount of rotational (angular) movement and the amount of linear movement. The third library corresponds to `Odometry` from `nav_msgs.msg`, this allows to inform the position and velocity of the robot. A set of libraries is also imported for mathematical calculations and to convert a quaternion rotation (robot orientation) to the corresponding Euler angles. Finally, NumPy is included for vector and matrix handling (Fig. 2).

The next section of the code is the block corresponding to the initialization of the ROS connections. In this block, the nodes are asked to subscribe and to publish messages under the corresponding topics, in our case-specific velocity and odometry topics. Also in this section, the pose values are reported (Fig. 3).

The next block of code defines the use of the sensor values in the robot model to estimate the position in the navigation environment, and then produce the movement of the robot if it is not yet within the tolerance range of the target point. This is the general control code of the robot, this code can be modified so that the target point corresponds to the estimation made by the robot itself from the location of neighboring robots, which can be detected from the LiDAR, as advanced in our research, or from a more complex sensor such as a digital camera, which is proposed as the future development of our work.

Two gains, K_1 and K_2 are used to adjust the robot velocity (linear and rotational), these values can be adjusted according to the laboratory behavior of the robot. The first task of this section of the code is to estimate the values of

ρ (distance between the robot and the target position) and ϕ (error between the direction of the robot and the direction from the origin to the target position) from the robot model. This can be done concerning a global reference, or a local one set with respect to the robot readings. After defining its location, control signals are sent to the robot to reduce the error to the target position. Finally, a message is sent when the robot is within the tolerance region of the target point (Fig. 4).

At the end is the `Main` section of the code. The objective is to keep the robot moving until the task is completed. Here you can include conditions or events that force the robot to leave the target point, for example, if the grouping criterion by QS (activation of behaviors by population size) has not been met or if you want to activate a new behavior (Fig. 5).

Gazebo is a 3D simulator that can show the behavior of robots according to the ROS code. To implement this simulation with the above code can be run on the terminal:

```
$ roslaunch turtlebot3_gazebo
turtlebot3_empty_world.launch
```

The code shown is only the structure that allows to read the sensors, estimate the position of the robot, and send the motion signals. However, it is a complete code that can be modified to implement the motion algorithms according to the navigation strategy to be evaluated in the robot.

Conclusion

This article presents the most important implementation details when developing motion planning schemes on the TurtleBot3 Burger platform using ROS. Both the basic information about this platform and some useful Python code structures for its management are presented. This work was developed during the implementation of flocking schemes with the robot, for which the performance of algorithms was evaluated on one or two robots, and then scaling the behavior to dozens of agents. During these tests, several difficulties were encountered, such as synchronization problems, and message sending between robots and control computer (network latency), which although not explicitly detailed because they do not affect the performance of the algorithm, they do raise the need to continue working on the implementation on the platform. Leaving these elements aside, the flocking behavior, about the strategy proposed for its implementation in our research, is feasible from the results, particularly with this robot, and formulates new lines of work that include the possibility of new sensors in the agents (digital cameras), new customized agents with similar functionality (agents built in our laboratory), and even study of the interaction between different populations, with different objectives.

Figure 3

ROS connection.

```
class turtlebot():
    def __init__(self):
        # Create node, publisher and subscriber
        rospy.init_node('turtlebot_controller', anonymous=True)
        self.velocity_publisher = rospy.Publisher('/cmd_vel', Twist, queue_size=10)
        self.pose_subscriber = rospy.Subscriber('/odom', Odometry, self.callback)
        self.pose = Odometry()
        self.rate = rospy.Rate(10)

# Response value of pose received
def callback(self, data):
    self.pose = data.pose.pose.position
    self.orient = data.pose.pose.orientation
    self.pose.x = round(self.pose.x, 4)
    self.pose.y = round(self.pose.y, 4)
```

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Figure 4

Sensing, position estimation and motion.

```
def move2goal(self):
    K1=0.5
    K2=0.5
    goal_pose_ = Odometry()
    goal_pose = goal_pose_.pose.pose.position
    goal_pose.x = input("Set_x_goal:")
    goal_pose.y = input("Set_y_goal:")
    distance_tolerance = input("Tolerance:")
    vel_msg = Twist()
    r = sqrt(pow((goal_pose.x - self.pose.x), 2) +
             pow((goal_pose.y - self.pose.y), 2))
    while r >= distance_tolerance:

        r = sqrt(pow((goal_pose.x - self.pose.x), 2) +
                 pow((goal_pose.y - self.pose.y), 2))
        psi = atan2(goal_pose.y - self.pose.y, goal_pose.x - self.pose.x)
        orientation_list = [self.orient.x, self.orient.y, self.orient.z,
                           self.orient.w]

        # Adjust according to navigation algorithm
        (roll, pitch, yaw) = euler_from_quaternion(orientation_list)
        theta = yaw
        phi = theta - psi
        if phi > np.pi:
            phi = phi - 2*np.pi
        if phi < -np.pi:
            phi = phi + 2*np.pi

        vel_msg.linear.x = K1*r*cos(phi)
        vel_msg.angular.z = -K1*sin(phi)*cos(phi)-(K2*phi)

        # Publishing input
        self.velocity_publisher.publish(vel_msg)
        self.rate.sleep()
    # Stopping the robot after the movement is over
    vel_msg.linear.x = 0
    vel_msg.angular.z = 0
    self.velocity_publisher.publish(vel_msg)
```

Figure 5

Continuous robot navigation.

```
if __name__ == '__main__':
    x = turtlebot()
    while 1:
        try:
            x.move2goal()
        except:
            pass
```

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Swarm behavior simulator with bacterial Quorum Sensing

Simulador de comportamiento de enjambre con Quorum Sensing bacteriano

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One of the most useful tools in the design of path-planning solutions is simulators. Thanks to them, it is possible to predict the performance of certain control strategies. In this paper, a simulator is presented that implements a swarm of automatons, which perform a wild motion in a user-selected environment. The robots will have the quality to avoid collisions with different obstacles that affect their mobility since they are equipped with proximity sensors. The interface of this simulator was designed entirely with the Qt Designer software. Successful configurations that replicate the performance of the real prototype are presented.

Keywords: Path-planning, quorum sensing, simulator, software, swarm

Una de las herramientas más útiles en el diseño de soluciones de planificación de trayectorias son los simuladores. Gracias a ellos, es posible predecir el rendimiento de determinadas estrategias de control. En este trabajo se presenta un simulador que implementa un enjambre de autómatas que realizan un movimiento salvaje en un entorno seleccionado por el usuario. Los robots tendrán la cualidad de evitar colisiones con diferentes obstáculos que afecten a su movilidad ya que están equipados con sensores de proximidad. La interfaz de este simulador se ha diseñado íntegramente con el software Qt Designer. Se presentan configuraciones exitosas que replican el desempeño del prototipo real.

Palabras clave: Enjambre, Planificación de rutas, quorum sensing, simulador, software

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Introduction

Motion planning is a critical aspect of programming an automaton, or a robot (Ichter et al., 2018; Mohanan & Salgoankar, 2018). It allows the robot to interact efficiently with its environment and enables it to move around dynamically, rather than being limited to its visible range. To address this need, motion planning simulation software can be developed. This software can be designed with certain basic functionalities and rules (Patle et al., 2019).

The motion planning simulation software in question implements a swarm of automatons that move around in a user-defined environment. These robots are equipped with proximity sensors, which allow them to avoid collisions with various obstacles that may affect their mobility. When the sensor detects the presence of an obstacle, the robot will randomly change direction to continue moving around in a wild, unpredictable manner (Bobadilla et al., 2012).

The user can choose the dimensions of the environment in which the automatons will be moving (Martínez et al., 2012). This environment is divided into a grid, which defines the regions where the automatons will be able to move. These regions are assigned weight values, which determine where the robots will tend to converge to reach the quorum, which is also defined by the user. The quorum is achieved when the automatons compare the weight values and the number of automatons present in each region.

The process of designing and programming this simulation software involves several steps, starting with the interface design and ending with the display of the quorum results (Khan et al., 2017). The interface is designed using the Qt Designer software, which makes it easy to position and size all the elements. The design is also focused on making it easy for the user to interact with the simulator. The final result of the interface design will be discussed in more detail later.

Literature review

(Huang et al., 1995) discuss the design and implementation of the simulator PowerMill, a novel transistor level simulator for the simulation of current and power behavior in vlsi circuits. They can form robust interspecies networks - bacterial communities - via sophisticated communication protocols. (Flikkema & Leid, 2005) assert that the improved understanding of these communities in the last decade provides a new model for swarm intelligence with distinct advantages, including ease of laboratory experimentation, explicit coupling of communication and behavior, and intergenerational dynamics. (Hsieh et al., 2008) present a biologically inspired approach to the dynamic assignment and reassignment of a homogeneous swarm of robots to multiple locations,

which is relevant to applications like search and rescue, environmental monitoring, and task allocation. This paper studies self-organized flocking in a swarm of mobile robots. (Ferrante et al., 2012) present Kobot, a mobile robot platform developed specifically for swarm robotic studies, briefly describing its sensing and communication abilities. (Korani, 2008) present a new algorithm for PID controller tuning based on a combination of the foraging behavior of E coli bacteria foraging and Particle Swarm Optimization (PSO). This paper describes some of the results obtained after the design and implementation of a discrete cellular automata simulating the generation, degradation and diffusion of particles in a two dimensional grid where different colonies of bacteria coexist and interact. This lattice-based simulator use a random walk-based algorithm to diffuse particles in a 2D discrete lattice (Gómez & Rodríguez, 2011). To keep the level of quorum sensing molecules below the activation threshold (Lo et al., 2015) propose a biological controller that can generate different concentration levels of inhibitors under different environment conditions. An existing quorum sensing strategy enables a swarm to alter collective behavior after a decision, but has not been evaluated under local communication restrictions. (Cody & Adams, 2017) combine these strategies to enable a swarm to detect when a majority of agents support a site and cease deliberation in order to rapidly build a consensus. One of the subject of (Roobahani & Handroos, 2019) is that the proposed control method combines a directed random search method and real-time simulation to develop an intelligent controller in which each generation of parameters is tested on-line by the real-time simulator before being applied to the real process. (Martínez et al., 2020) propose a strategy for the coordination of a swarm of robots in an unknown environment.

Problem statement

Designing and programming a motion planning simulation software that allows for the implementation of a swarm of automatons that can perform wild movement in a user-selected environment. These automatons should be equipped with proximity sensors that allow them to detect and avoid collisions with obstacles that may affect their mobility. Additionally, the environment should have a grid system that defines regions for the automatons to move in, with each region being assigned a weight value. The automatons should be able to compare the weight values and number of automatons present in each region in order to reach a quorum, which is also defined by the user. The software should have a user-friendly interface that allows for easy interaction with the simulator, and should provide a detailed explanation of the design and programming process.

The motion planning simulation software should be able to handle dynamic and constantly changing environments,

as this is an important aspect of modern automation. The automatons should be able to move randomly while avoiding obstacles, and should be able to converge on a specific region based on the weight values and number of automatons present in that region. The user should be able to adjust the dimensions of the environment, as well as the weight values and quorum requirements. The interface should be designed using the Qt Designer software, and should prioritize ease of use for the user.

The final result of the simulation software should include a detailed explanation of the design and programming process, including the steps involved and the methods used to achieve user interaction. The software should also display the quorum results, allowing the user to see how the automatons have converged on specific regions based on the weight values and number of automatons present. Overall, the motion planning simulation software should provide a flexible and user-friendly platform for programming and interacting with a swarm of automatons in dynamic environments.

Methods

In terms of the programming process, the first step is to define the functionalities and rules that the simulation software will follow. This may include the algorithms that the automatons will use to avoid collisions, the criteria for determining the quorum, and the rules for how the automatons will move around in the environment. Once these details have been ironed out, the next step is to implement the code that will bring the simulation to life. This may involve using programming languages such as C++ or Python to create the automatons, the environment, and the various algorithms and rules that will govern their behavior.

Once the code has been written, the next step is to test the simulation to ensure that it is working as intended. This may involve simulating different configurations, such as different numbers of automatons or different environments, to see how the automatons behave in each case. This testing process will help to identify any bugs or issues that need to be addressed before the simulation is ready for use.

Once the simulation is working as intended, the final step is to create the user interface that will allow the user to interact with the simulation. This may involve designing and building a graphical user interface (GUI) using a tool such as Qt Designer or using a command-line interface (CLI) that allows the user to input commands and see the simulation results in a text-based format.

Overall, the process of designing and programming a motion planning simulation software involves some steps, including defining the functionalities and rules, implementing the code, testing the simulation, and creating the user interface. By following these steps, it is possible to create a software tool that can be used to simulate the motion

and behavior of automatons in a user-defined environment (Fig. 1).

The first step to performing the simulation is to load the environment in which the robots interact (Figs. 2 and 3). In this configuration the simulator will give the option to load an environment that can be any file in JPG or PNG format that has a white background and no borders. Click on load environment, and it will direct it to the D:/ directory of the computer to select the desired environment.

The loaded environments will be located in the simulator executable folder, more specifically in the maps folder. These loaded environments, found in the maps folder, will enable a user to experience their custom simulations within the simulator executable (Fig. 4).

When selecting the environment the software will give the option of a treatment to include in the simulation. Thanks to the OpenCV library any loaded environment will change to a composition of white and black pixels, creating a new explorable environment for the robots which is named "1", clarifying as an explorable environment the white pixels and as obstacles the black pixels. This means that the environment can be changed, adapted, and customized to the robot's needs, making it a very versatile tool in terms of simulation possibilities (Fig. 5).

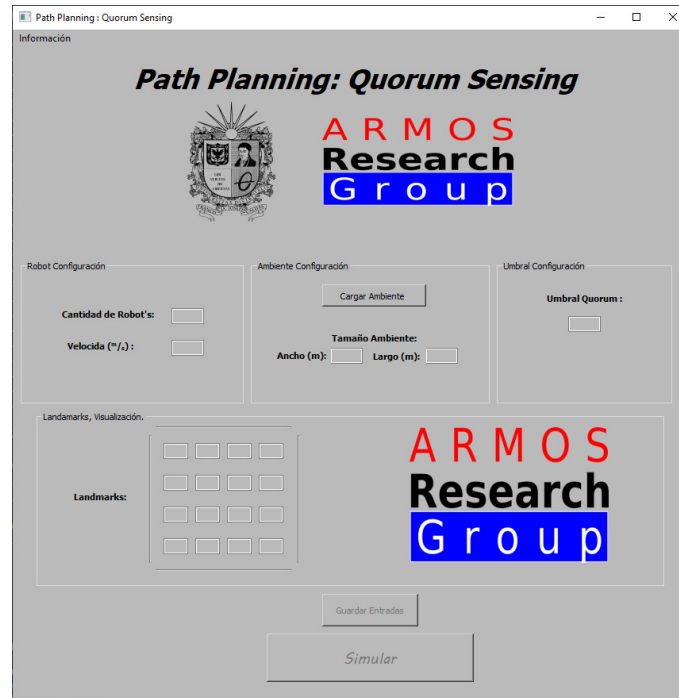
Once the environment is loaded, the size of the environment is defined based on the size of the image, which is 800×600 . The next step is to define the parameters of the robot, such as the number of robots and their speed (Fig. 6). The default size is given by the robot belonging to the ARMOS research group, which has dimensions of $0.61 \text{ cm} \times 0.61 \text{ cm}$. To ensure that the environment is accurate, it is important to properly set the parameters of the robot. Therefore, it is important to select the proper number of robots and adjust their speed to ensure that they move at a suitable rate.

The number of robots defining the Quorum Sensing must be adjusted in coherence with the total population size. For the number of robots, the maximum is defined as corresponding to 4% occupancy, as it is considered the right number for a relevant threshold performing a task; the minimum number is defined at the user's discretion (Fig. 7). The speed will depend on the physical construction of the robot we want to simulate, this will be reflected in the scan time and the percentage of occupation of our robot in the loaded environment. To define the quorum threshold, the user is free to decide the number of robots needed to meet it. Therefore, the number of robots within the Quorum Sensing needs to be adjusted according to population size, with a minimum and maximum number defined.

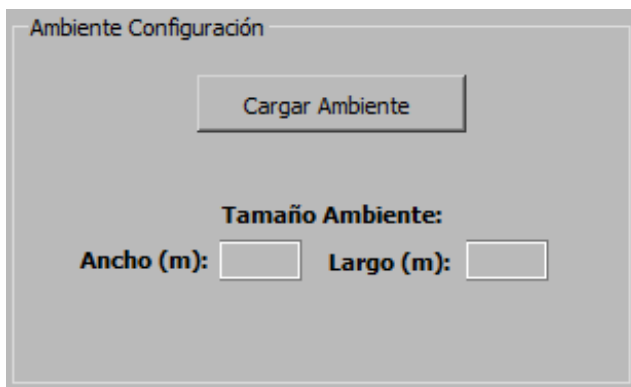
To define the place where the quorum will occur, the regions in the environment must be defined with a corresponding performance value, which is assigned using weight values or landmarks, which will give information to

Figure 1

Path planning simulator interface.

**Figure 2**

Environment configuration.



the robots about the importance of that region and the higher this value is, the more attractive it will be for the robots (Fig. 8). The value of each landmark will be a maximum of 10. Each region will be measured about the others, based on the criteria assigned to each of them so that a single region with a higher value is more likely to be chosen than several regions with lower values. Thus, the value assigned to each

region will provide information about how attractive it is for the quorum.

Here the user will enter the weight values he wants for the regions of the environment and on the right side he will have a preview of the previously loaded environment. Once the basic values for the simulation are obtained the user will click on save, this will generate the values in the program base and then run the simulator in the Python Pygame platform. The simulator will process the user's weight values, which it reads from the program base, and then apply them to generate an environment on the Python Pygame platform.

Results

We will now review each of the functionalities offered by the program and its great versatility in representing different types of scenarios as required by the researcher. One of the possible variables when simulating is the size of the environment, to give context an environment of $100\text{ m} \times 50\text{ m}$ and another of $75\text{ m} \times 20\text{ m}$ will be simulated as shown in Fig. 9 and Fig. 10 respectively. These scenarios will be compared to one another, taking into account the difference in size and its effect on the results obtained.

As can be seen in the figures above, the environment did not change in size or shape, as it remains constant regardless of the size of the environment. However, the

Figure 3

Environment selection directory for the simulator.

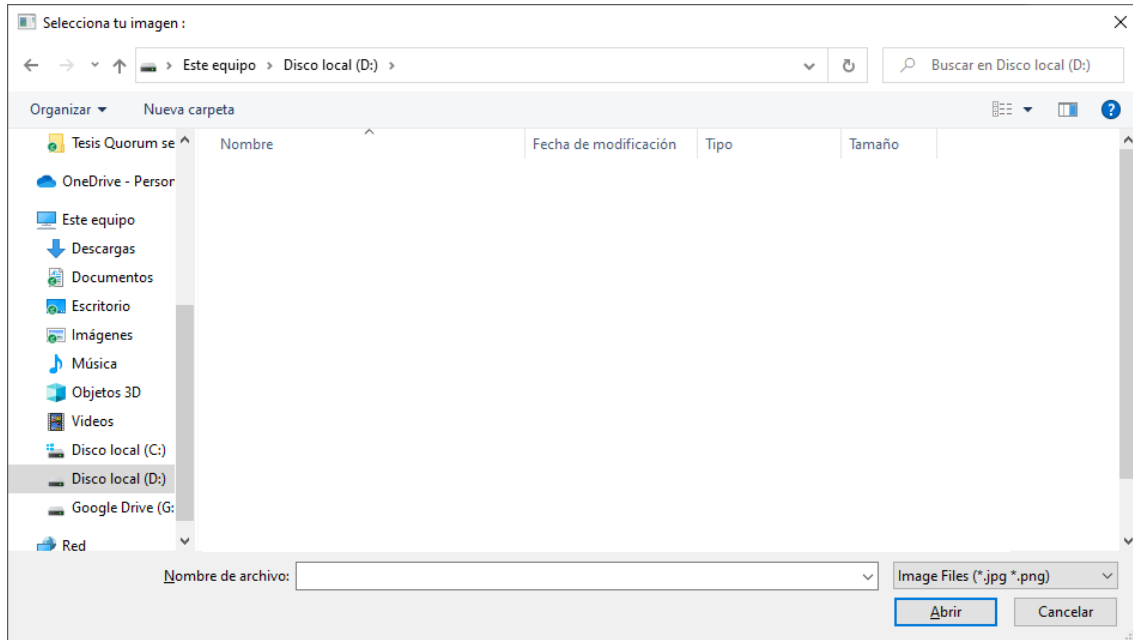


Figure 4

Pre-loaded environments for the simulator with their respective locations.

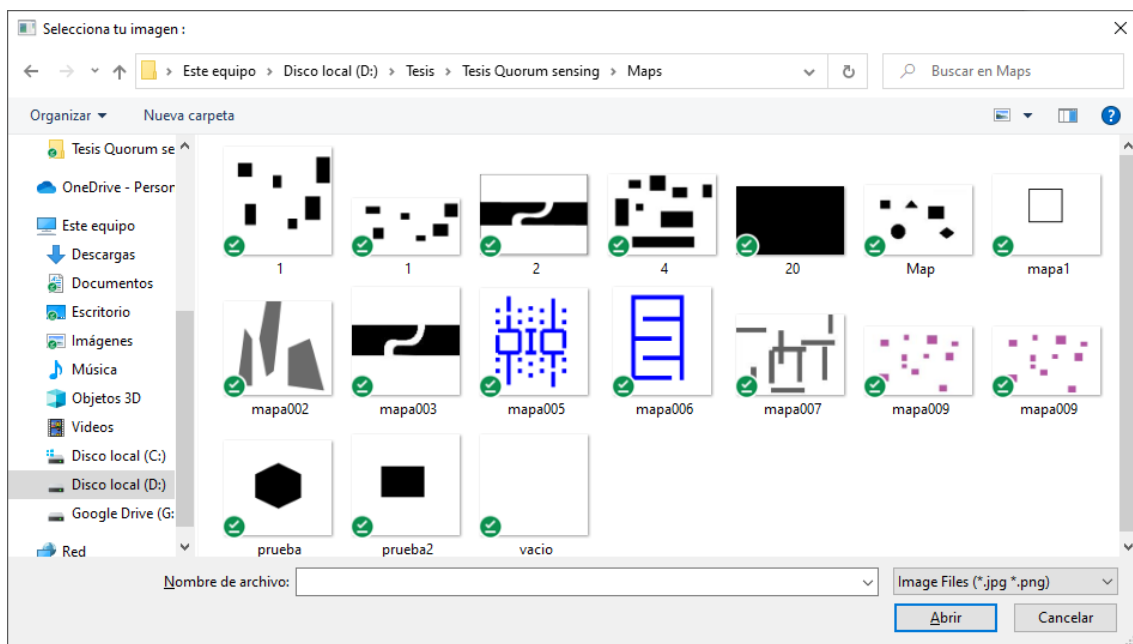


Figure 5

Environment modified and saved by the simulator:

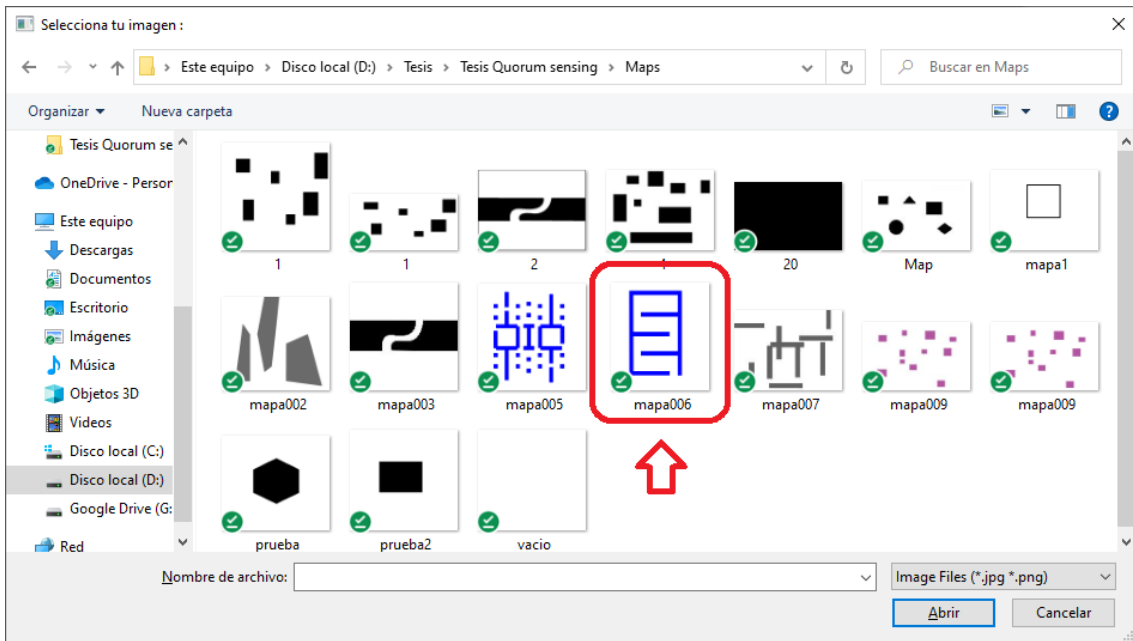


Figure 6

Configuration of robot parameters.

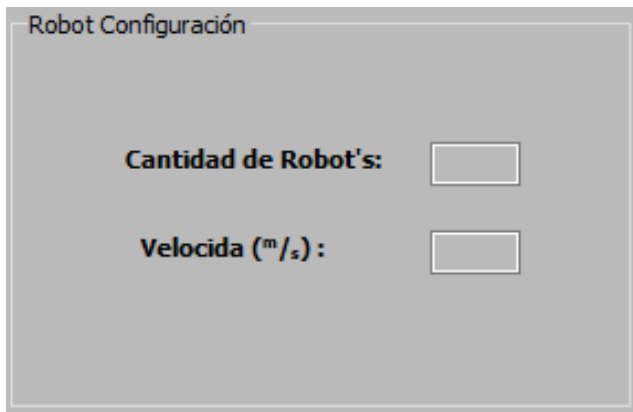
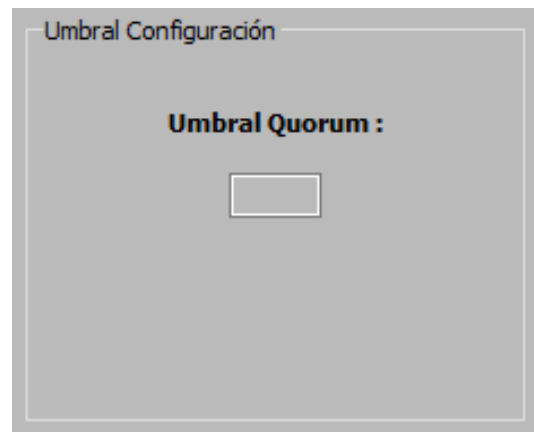


Figure 7

Setting the quorum threshold value.



robots changed as the size of the environment changed, by having a larger area in the environment the robots look smaller in comparison, this means that the true size of the robots remains constant regardless of the size of the environment. The scale of the environment changes according to the simulation need, but the space used on the screen is optimized. The optimized size of the environment

provides users with an improved visual representation that is easy to interact with.

To simulate various types of scenarios, our program allows loading different types of environments in .jpg or png format as shown in Fig. 11 and Fig. 12. The user can use the drop-down menu to select one of the many pre-existing environments or load a new environment of their own.

Figure 8

Assignment of landmarks to the simulator as a preview of the loaded environment.



In a navigation environment, it is important to define the number of robots that will perform the search task. With this objective in mind, the program allows the implementation of several robots that do not exceed 4% of the area of the environment. In this case, 35 robots were implemented in an obstacle-free environment of 75 m × 20 m as shown in Fig. 13.

To implement Quorum Sensing the robots will move using wild movement. Through the initial interface a certain quorum threshold is determined in a cell chosen by the user and weight is given to this zone, depending on this weight stipulated by the user, the robots that exceed the quorum threshold in a zone will wait a time directly proportional to the weight of the zone. Fig. 14 shows how several red robots are concentrated in different zones of interest, blue robots are waiting for more robots to complete the quorum and green robots are scanning the environment in search of a zone of interest. The robots' movements are chaotic, but the Quorum Sensing algorithm helps to control their overall behavior by determining the necessary quorum for a given region. In this way, the robots can efficiently explore a given area and detect regions of interest.

Once the user wishes to finish the simulation, he/she can click on the **Finish** button to enter the results screen, where he/she will find data of interest such as the number of robots used, the environment, and its divisions, the total simulation time, the time it took to reach quorum in any zone and the concentration of robots per zone of interest, this concentration of robots is given with a color palette explained in the upper left part of the results screen as shown in Fig. 15. On this results screen, the user can analyze the performance of the robots in the environment by checking how much time

they needed to reach a quorum, or how many robots were used.

Despite the efforts made to create a simulation that matches real life, it was not possible to achieve accurate collisions between robots and environments due to the limitations of Pygame. Although the collisions work well most of the time, sometimes the robots can overlap with the objects and get trapped inside them, however, this problem could be solved by using environments included in the program by implementing fixed and well-determined hitboxes; when a user loads his environment it is not possible to accurately determine these hitboxes, so this kind of problems can occur. Thus, the only way to guarantee a more accurate collision between the robots and their environment is to create a simulation using different programming languages or libraries which are designed specifically for game development and animation, as these provide greater control over the physics of collisions. Therefore, while Pygame provided a useful framework to create a simulation and enable the robots to move realistically, the limitations of this program meant that it was not possible to guarantee an accurate collision between robots and their environment.

Conclusion

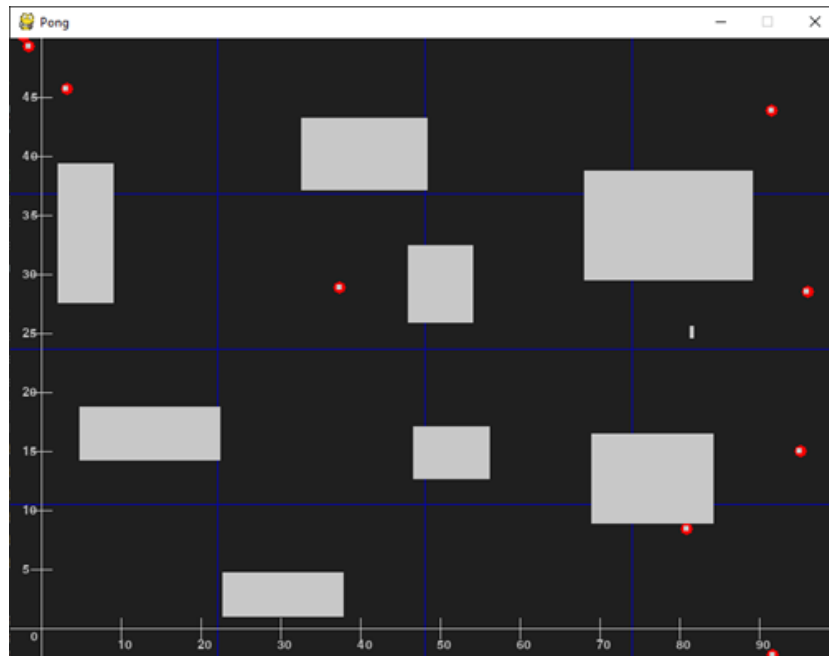
The use of Python as design software for the code used facilitated the process in the generation of both the robot and its interaction with the environment since thanks to its object-based programming it is possible to add qualities that in other software may take a longer process. This object-based programming made it easier to implement changes to the robot's behavior, without having to completely re-program it.

The versatility of the software to perform the simulation on environments established by the user generates endless possibilities; having only as a restriction that the environment is not with margin since it is one of the limitations of the software. This capability, along with the other features of the software, allows users to craft a wide range of simulations, limited only by their imaginations and the capabilities of the software.

The software gives positive results when performing the navigation simulation for a group of autonomous robots through the movement strategy formulated and applied by the research group. This strategy derives its working principle from a simplified model of bacterial interaction; these results are shown in the quorum values reached by the software and previously introduced by the user; these values have a direct interaction with the environment as well as the other values defined by the user. The software produces robust results, with the quorum values closely mirroring those which have been defined by the user. This is a testament to the effectiveness of the software, as it can accurately calculate the interactions between

Figure 9

100 m × 50 m navigation environment.

**Figure 10**

75 m × 20 m navigation environment.

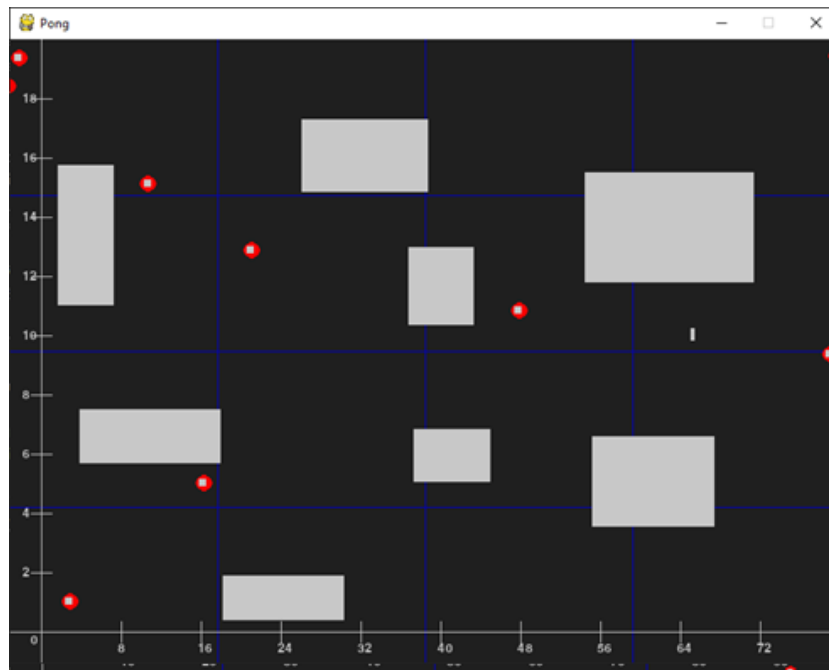


Figure 11

Loading of different environments (1).

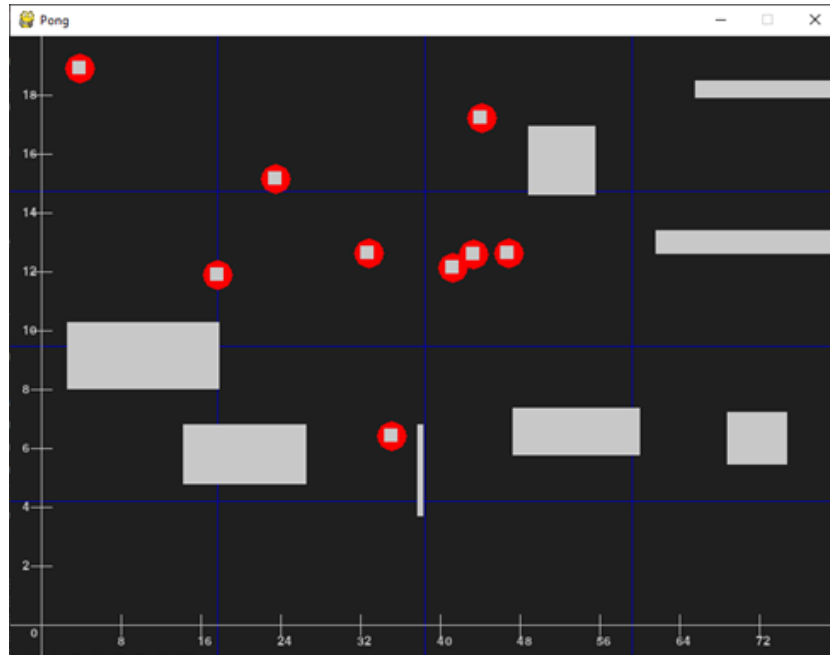


Figure 12

Loading of different environments (2).

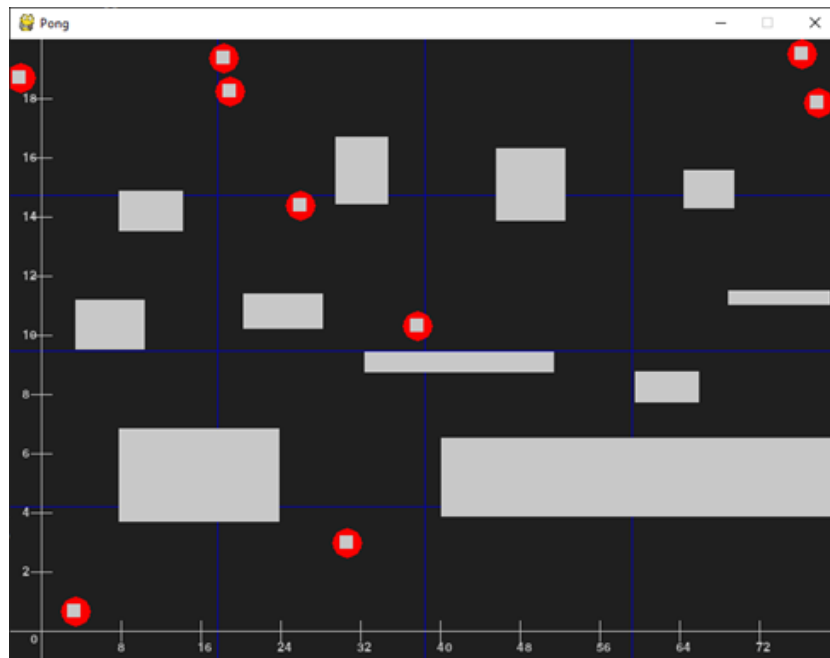
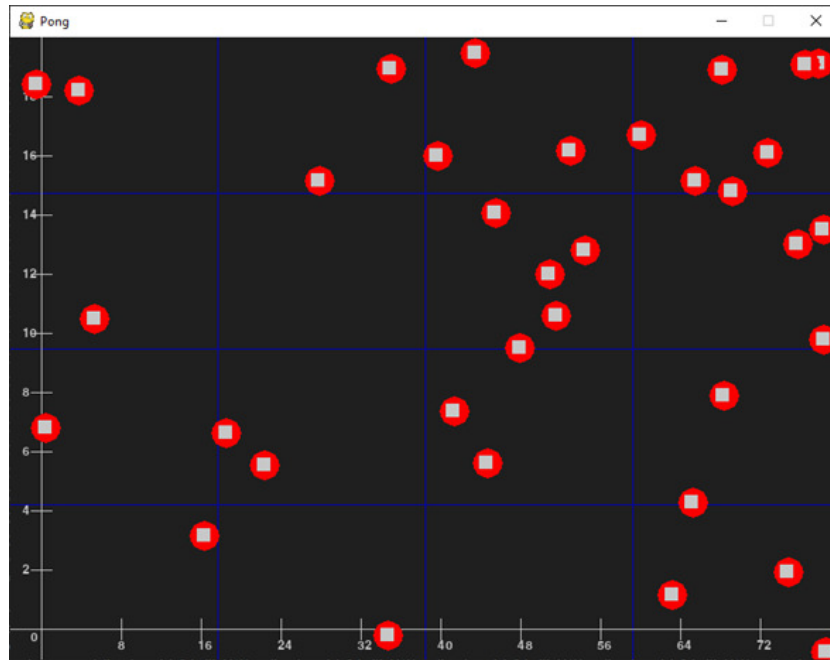


Figure 13

Loading 35 robots in a simulation.



various parameters, and generate robust results following the previously defined values.

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Figure 14

Robots exploring an environment.

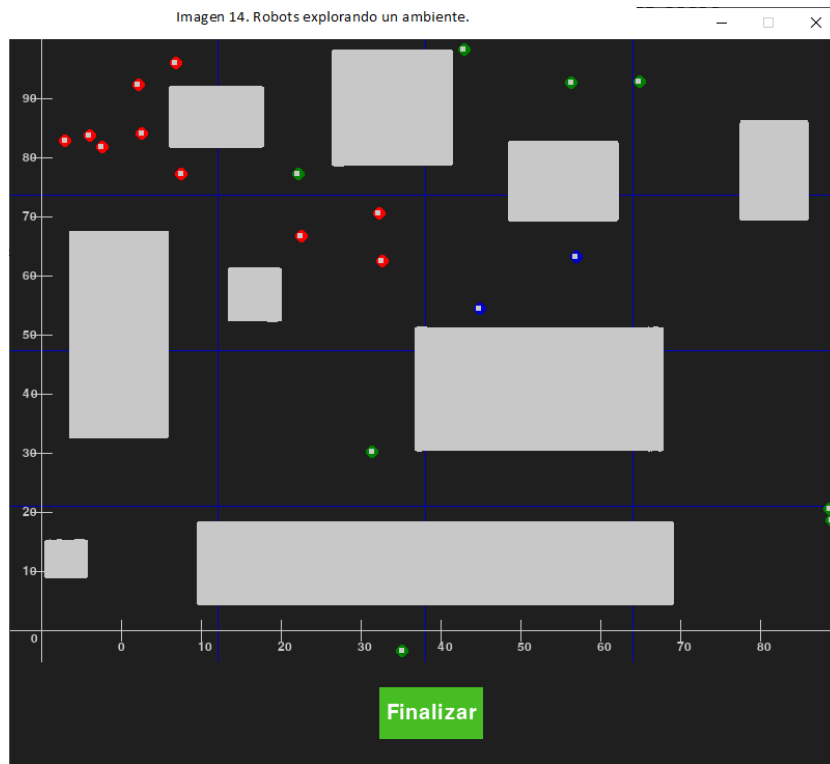


Figure 15

Results screen.



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Instrucciones para los autores

Tekhnê

Tecnología al servicio de la sociedad

Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

Revista Tekhnê
Universidad Distrital Francisco José de Caldas
Facultad Tecnológica

Alcance y política editorial de la revista

La revista **Tekhnê** es una revista institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas (Colombia). Es arbitrada, y acepta trabajos originales en el campo de la ingeniería, la tecnología y las ciencias aplicadas, con la condición de que sean producto de trabajos de investigación. Desde su primer número en el año 2003, la revista ha mantenido su regularidad.

Posee un carácter científico-académico, y atiende a la comunidad nacional e internacional especialista en áreas de ingenierías eléctrica, electrónica, mecánica, de sistemas, industrial y civil. Publica resultados de investigación en inglés (artículos originales e inéditos), y está completamente abierta a especialistas de todo el mundo en calidad de autores y/o lectores. Es arbitrada mediante un proceso doble ciego, con rotación continua de árbitros.

La revista **Tekhnê** posee una periodicidad semestral, coincidente con los semestres académicos de la Universidad Distrital. La publicación se realiza los meses de junio y diciembre de cada año. El proceso de evaluación de los trabajos sometidos para la publicación contempla una etapa de aceptación inicial por parte del Comité Editorial, quien verifica el cumplimiento de los parámetros editoriales, y una evaluación por pares académicos mediante un proceso doble ciego. El tiempo que toma decidir sobre la aceptación de un trabajo nunca supera los seis (6) meses a partir de la fecha de recepción.

La revista **Tekhnê** está comprometida con altos estándares de ética y toma las medidas posibles para evitar las malas prácticas como el fraude y el plagio. Todos los autores deben declarar que sus manuscritos son originales, inéditos y de su autoría, condición necesaria para ser considerados por el Comité Editorial. La revista **Tekhnê** también se compromete a garantizar una justa, objetiva y rápida revisión de los manuscritos tanto por árbitros como por parte del Editor. Los autores

reconocen que han dado a conocer cualquier conflicto real o potencial de intereses con su trabajo o de beneficios parciales asociados a través de la cesión de derechos.

La revista **Tekhnê** es financiada por la Universidad Distrital Francisco José de Caldas, razón por la cual NO cobra por procesamiento y/o publicación de artículos (APCs).

Tipos de artículos aceptados

La revista publica exclusivamente artículos de Investigación Científica y Tecnológica (según clasificación del Índice Nacional de Publicaciones Científicas y Tecnológicas Publindex de Colciencias), los cuales se caracterizan por presentar resultados originales de proyectos terminados de investigación, con secciones claramente diferenciadas de introducción, metodología, resultados y conclusiones. Otro tipo de artículos como los denominados de reflexión, revisión, artículos cortos o reportes de casos no son aceptados, y serán rechazados por el Comité Editorial sin surtir proceso alguno de evaluación.

Formato del manuscrito

En cuanto a estructura, deben ser evidentes las secciones de introducción, metodología, resultados, conclusiones y referencias. El resto del documento se debe conformar en concordancia con su contenido. La longitud no debe superar las 25 páginas en su totalidad. En la parte inicial de la primera página se debe incluir: (1) Un título del manuscrito (en español e inglés), corto, descriptivo del contenido y atractivo para el lector. (2) Nombre completo de los autores y detalles de afiliación institucional, incluido correo electrónico. (3) Resumen (en español e inglés) del manuscrito con un tamaño máximo de 250 palabras, que establezca el objetivo, la metodología, los resultados y principales conclusiones. (4) Palabras claves, máximo cinco, en minúsculas y separadas por comas.

En cuanto al formato de documento solicitado a los autores, se pide utilizar LaTeX de acuerdo con la plantilla disponible en el portal web de la revista. No se debe modificar el formato de la plantilla. Las tablas y figuras deben ser claras y nítidas, insertadas como archivos EPS con la mayor calidad posible. Se pide que estas figuras sean remitidas en un archivo comprimido por separado. Si se usan líneas o figuras en colores, no se debe usar colores claros (amarillos, celestes y similares). El Editor se reserva el derecho de eliminar toda figura o tabla que no cumpla las normas. Toda figura, tabla, ecuación o referencia incluida en el manuscrito debe estar referenciada/citada en el cuerpo del documento. Las referencias deben manejar correcto estilo APA sexta edición. No se deben utilizar notas al pie de página, y usar máximo tres niveles para los títulos. Se puede incluir una sección de Agradecimientos (altamente recomendada), redactada en forma sobria, de no más de cuatro líneas justo después de las Conclusiones.

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Los manuscritos son publicados siguiendo el estilo APA sexta edición. Esto es realizado en la diagramación, y es transparente para los autores.

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El Editor se reserva el derecho, y así lo acepta el(la)(los) autor(a)(es) con el sólo envío del manuscrito, de realizar modificaciones con el objeto de lograr una mejor presentación e impacto del trabajo. Estas modificaciones pueden incluir cambios en el título, resumen, palabras clave, figuras, tablas y texto, entre otros, cambios que no afectan, según el Editor, la esencia del trabajo enviado por los autores. En particular, figuras que no pueden ser bien reproducidas pueden ser eliminadas por el Editor. Las referencias incompletas serán también eliminadas por exigencias de las bases de datos.

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Los autores deben enviar sus artículos a través de la aplicación para tal fin del Open Journal System (<http://revistas.udistrital.edu.co/ojs/index.php/tekhne/index>) en formato digital, adjuntando:

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- La carta de cesión de derechos (según formato).

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- Solicitud expresa de considerar el artículo para publicarlo en la revista **Tekhnê**.
- Título completo del trabajo.
- Nombres completos de todos los autores, con detalle de entidad a la que se encuentran vinculados, dirección e-mail institucional, títulos académicos, ciudad y país.
- Certificación de la originalidad y el carácter inédito del artículo.
- Exclusividad de su remisión a la revista **Tekhnê**.
- Confirmación de la autoría con la firma de todos los autores.
- Institución que financió o avaló el proyecto.

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El proceso que sigue la revista para la evaluación y publicación de trabajos es el siguiente:

- Recepción del manuscrito (primera versión, convocatoria permanente)
- Verificación de normas por parte de auxiliar de la revista
- Notificación a autores de recepción, solicitud de ajustes de forma y de diligenciamiento de formato de datos de autores
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- Notificación a autores de si el manuscrito entra o no a evaluación por parte de pares
- Envío de manuscrito a pares seleccionados
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- Recepción de manuscrito (tercera versión)
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- Envío de versión final a autores para verificación de errores y aprobación final
- Publicación del artículo
- Notificación a autores de publicación
- Entrega de ejemplares a autores

Contacto

Para cualquier solicitud de información adicional puede comunicarse con:

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Instructions for authors

T e k h n ê

Tecnología al servicio de la sociedad
Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

Tekhnê Journal
Universidad Distrital Francisco José de Caldas
Facultad Tecnológica

Scope and editorial policy of the journal

The **Tekhnê** journal is an institutional journal of the Technological Faculty of District University Francisco José de Caldas (Colombia). It is arbitrated, and accepts original articles in the field of engineering, technology and applied sciences on the condition that they are the product of research work. Since its first issue in 2003 the journal has maintained its regularity.

It has a scientific-academic nature and attends the specialist national and international community in the areas of electrical, electronics, mechanical, systems, industrial and civil engineering. Publishes research results in English (original and unpublished articles), and is fully open to experts from around the world as authors and/or readers. It is arbitrated by a double-blind process, with continuous rotation of evaluators.

The **Tekhnê** journal has twice a year periodicity, coinciding with the academic semesters of the District University. The publication is made in June and December each year. The evaluation process of the papers submitted for publication includes a stage of initial acceptance by the Editorial Committee, which verifies compliance with the editorial parameters and an evaluation by academic peers through a double blind process. The time taken to decide on the acceptance of a paper never exceeds six (6) months from the date of receipt.

The **Tekhnê** journal is committed to high ethical standards and take possible measures to avoid bad practices such as fraud and plagiarism. All authors must declare that their manuscripts are original, unpublished and of his own, needed condition to be considered by the Editorial Committee. The **Tekhnê** journal also is committed to ensuring a fair, objective and quick review of manuscripts both referees as by the Editor. The authors recognize that they have disclosed any actual or potential conflict of interest with their work or partial benefits associated through the transfer of rights.

The **Tekhnê** journal is funded by the District University Francisco José de Caldas, which is why it does NOT charge for processing and/or publishing articles (APCs).

Types of articles accepted

The journal publishes only Scientific and Technological Research articles (as classified by Publindex, the National Abstracting and Indexing System for Serial Publications in Science, Technology and Innovation of Colciencias), which are characterized by original results of completed research projects with clearly distinct sections of introduction, methodology, results and conclusions. Other articles as called reflection, review, short articles or case reports are not accepted and will be rejected by the Editorial Committee without dispensing any evaluation process.

Manuscript format

Regarding the structure, should be evident the sections of introduction, methodology, results, conclusions and references. The rest of the document must conform in accordance with its contents. The length should not exceed 25 pages in full. In the initial part of the first page should include: (1) A manuscript title (in Spanish and English), short, descriptive of the content and attractive to the reader. (2) Full name of the authors and institutional affiliation details, including email. (3) Abstract (in Spanish and English) of the manuscript with a maximum size of 250 words, which set the objective, methodology, results and major conclusions. (4) Keywords, up to five, lowercase and separated by commas.

Regarding the document format requested by authors, it is requested to use LaTeX according to the template available in the journal's web portal. The format of the template should not be modified. Tables and figures should be clear and sharp, inserted as EPS files with the highest possible quality. It is requested that these figures be submitted in a separate compressed file. If colored lines or figures are used, light colors (yellow, light blue, and similar) should not be used. The Editor reserves the right to delete any figure or table that does not comply with the rules. Any figure, table, equation, or reference included in the manuscript must be referenced/cited in the body of the paper. References must use the correct APA sixth edition style. Footnotes should not be used, and a maximum of three levels should be used for headings. An Acknowledgements section may be included (highly recommended), written soberly, of no more than four lines just after the Conclusions.

All source files must be submitted. In all cases, authors should submit, together with the images, a BibTeX file (a single *.bib file) with all the references used in the article, each reference with a unique key. This file can be generated from reference managers such as Mendeley and Zotero, or generated with tools such as JabRef.

Regarding the language and style of writing, the author must use simple sentences and avoid regionalisms. He must take special care to use the correct spelling and writing, according to the rules of language.

Publication format

The manuscripts are published following the APA style 6th edition. This is done in the layout, and is transparent to the authors.

Editing changes

The Editor reserves the right, and is accepted by the author(s) with the only article shipping, to make changes in order to achieve a better presentation and impact of the work. These modifications may include changes in the title, abstract, keywords, figures, tables and text, among others, changes that do not affect, according to the Editor, the essence of the work submitted by the authors. In particular, figures that can not be well reproduced can be eliminated by the Editor. Incomplete references will also be eliminated by demands of databases.

Sending manuscripts

Authors must submit their articles through the application for the purpose of the Open Journal System (<http://revistas.udistrital.edu.co/ojs/index.php/tekhne/index>) in digital format, attaching:

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- The transfer of rights letter (according to format).

The presentation letter should be addressed to the director and editor of the journal Prof. Fredy H. Martínez S., and it should include:

- Express request to consider the article for publication in **Tekhnê** journal.
- Full title of the article.
- Full names of all authors, detailing entity linked, institutional e-mail address, academic degrees, city and country.
- Certification of the originality and novelty of the article.
- Exclusivity of submission to **Tekhnê** journal.
- Confirmation of authorship with the signature of all authors.
- Institution financing the project.

The submission process consists of three stages:

1. Sending the article in PDF format. OJS is charged with a single uncompressed file.
2. Data recording. the basic data of the authors and article are registered in the OJS.
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The process followed by the journal for evaluation and publication of articles is as follows:

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- Receipt of the manuscript (second version) and authors data format
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- Notification to authors if the manuscript is sent or not to evaluation by peers
- Sending the manuscript to selected peers
- Reception peer evaluation

- Notification of evaluation to authors, and request corrections if they are relevant
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- Reception of the rights transfer letter
- Style correction and layout of the manuscript
- Send final version to authors for error checking and final approval
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- Delivery of copies to authors

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