Universidad Politécnica Salesiana

SMART TECHNOLOGIES, SYSTEMS AND APPLICATIONS

SMARTTECH-IC 2022

Third International Conferenceon Smart Technologies, Systems and Applications

Fabián R. Narváez / Fernando Urgilés / Teodiano Freire Bastos-Filho / Juan Pablo Salgado-Guerrero (Eds.)

This book contains the papers presented on poster sessions at the Third International Conference on Smart Technologies, Systems and Applications (SmartTech-IC 2022) held on November 16-18, 2022 in Cuenca, Ecuador. The SmartTech-IC conference aims to attract researchers, scientists and technologists from some of the top companies, universities, research groups, and government agencies from Latin America and around of the world to communicate their research results, inventions and innovative applications in the area of smart science and the most recent smart technological trends. SmartTech-IC 2022 was organized by the Universidad Politécnica Salesiana, a private institution of higher education with social purposes, nonprofit and co-financed from the Ecuadorian State.

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Teodiano Freire Bastos-Filho / Juan Pablo Salgado-Guerrero (Eds.)

Smart Technologies, Systems and Applications

SmartTech-IC 2022: Third International Conference on Smart Technologies, Systems and Applications

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SmartTech-IC 2022

2023

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Preface

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We would like to express our gratitude to all the authors who submitted papers to SmartTech-IC 2022, and our congratulations to those whose papers were accepted. Each submission was reviewed by at least three qualified reviewers chosen from our Program Committee (PC) based on their qualifications and experience. The papers were selected by Program Chairs and their selection was based on a series of criteria including the reviewers average score and comments provided by the Program Committee members.

We would also like to thank the PC members, who agreed to review the manuscripts in a timely manner and provided valuable feedback to the authors.

November, 2022
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Tire Pressure Optimization for a Competition Kart using the Box Behnken Method

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Abstract

In the present research, the pressures of a competition kart are optimized by applying the Box-Behnken method. Three analysis criteria are established, considering the types of driving in the engine settling, free tests and competition. Tire pressure adjustment and driver weight are considered as input variables and lap time on the track circuit is considered as the output variable. The study is carried out with a new engine (IAME X30) in the Austral Karting Championship. The results of the application of the method establish that the pressure of the front tires, both cold and hot, and the pressure of the hot rear tires influence the engine settling and competition tests. However, only the pressure of the front tires, both cold and hot, influences the free tests.

Keywords

Box Behnken, Karting, Optimization, Pressure, Tires, Driver's weight.

Introduction

Historically, Karting has been fundamental pillar in the motoring field, serving as a cradle for new drivers worldwide [1]. This sport was born in California, United States in 1956 when Art Ingles built the first Go kart vehicle in history powered by a lawnmower engine [2], the in 1958 the American company Go Kart Manufactory Co. focuses its processes on the manufacture of race karts [3]. In the same year, the regulatory body for sports activities (GKCA) Go Kart Club of America is founded, while, in 1960, the first karting races are organized in several European countries [4]. Specifically, in Ecuador, the sport appears in the year 1975 when the Mitad del Mundo kart track was built in Quito city [5]. In previous research, the importance of tires to improve the performance of Karting is emphasized, as well as the influence of psychological aspect on the pilot for the optimization of the lap time on the track, in this context two kinds of research are established, technical and psychological. In the technical aspect [6] it studies the aerodynamic resistance through CFD (Computational Fluid Dynamics), obtaining an aerodynamic penetration coefficient of 0.8, thus allowing for improvement in the lap times of the Go Kart in competition, on the other hand [7] it applies a brake kinetic energy recovery system, resulting in an average slowdown of 1.02 seconds per lap.

This research [8] uses Maple symbolic algebra software to optimize vehicle characteristics (such as frame stiffness and stabilizer bar), through a simulation that allows investigating how it affects the vehicle's maneuverability before executing any test on the track. In [9] and [10] the structure (chassis) of Karting is analyzed by means of finite element simulation. The first obtained a maximum stress of 2.928 e07 MPa and a maximum deformation of 2,654 mm, while the second obtained a maximum stress of 17,297 MPa and a maximum deformation of 1,413 mm, concluding in reinforcing areas such as the support node of the front wheels where the spindle is located and the area where the engine base is located. Finally, in the technical part [11] it uses a PPO (Proximal Policy

Optimization) algorithm, obtaining as a result that the car trained by the PPO algorithm accelerated 33.20% faster than the baseline vehicle, thus helping to improve vehicle times in the race. In the psychological aspect, articles such as [12, 13, 14, 15] use different tests and question-naires to determine a direct relationship between factors such as mood, concentration, tranquility, mental strength, relationship with the work team of the pilot and his performance on the track, obtaining positive results and leaving open the possibility of new psychological researches in the sports racing environment.

It is also important to mention that, articles [16, 17, 18, 19, 20, 21] focus on optimizing different types of variables using the Box Behnk-en method. Previous research focuses on the optimization of karting structural dynamics and driver psychology; however, no method has been found to study the influence of pressure on karting behavior in competition. Therefore, this article is oriented to the analysis of the in-fluence of tire pressure on the performance of karting, in different study parameters by applying the Box Behnken method.

Materials and Methods

In this section, the main topics that have to do with the selection of the study parameters, the instrumentation used in the experiment, the acquisition of data, and the validation of these are developed.

Study parameters

The engine used in this experimentation is new, for which three research stages are developed, under the driving parameters in the en-gine arrangement, in free tests and in competition.

Instrumentation

This section describes the main equipment used in the experi-ment seen in Table 1, considering that each team used complies with the

provisions of the Austral Karting Championship regulations. In addition to the devices, Table 2 defines the weight of the pilots and the total of the Karting.

Table 1
Main devices used in the experiment

Equipment	Description
Engine	IAME X30 125cc
Chassis	Kosmic 2020
Tires	MG red
Mychron 5	Instrument to take the data.
Manómetro	0 PSI – 40 PSI

Table 2
Weight of driver and total of karting

Description	Weight	Total weight
Pilot 1	84 kg	195.36 kg
Pilot 2	85 kg	196.36 kg
Pilot 3	55 kg	166.36 kg
Pilot 4	59 kg	170.36 kg

Circuit

The schematization of the circuit was carried out through the acquisition of data provided by Mychron 5, a device that has a GPS frequency of 25 Hz, in addition, to two satellite systems that allow accuracy in data collection, to subsequently intertwine the acquired data. with the RaceEstudio 3 program which generates a layout of the circuit where the experimentation was carried out.

Figure 1
Experimental Circuit
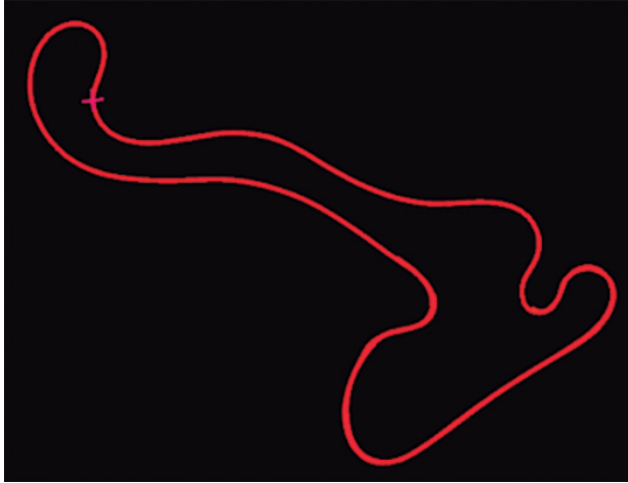
Input variables

The chassis calibration variables for a competition kart are front track width, rear track width, front axle height, rear axle height, camber angle, toe angle and tire pressure [22]. For the development of this experiment, only tire pressure is considered as input variables, because the method used must limit the number of variables, leaving the remaining variables for later researches.

To simplify the name of the input variables, the following abbreviations are considered:

- Hot front tire pressure (PNDC)
- Cold front tire pressure (PNDF)
- Hot rear tire pressure (PNTC)
- Cold rear tire pressure (PNTF)
- Pilot weight (PP)

Output variables

The goal of this research is to identify how tire pressures influence the time it takes for the pilot to complete a circuit of experimentation, for which, as an output variable, the following is considered:

- Time to complete the circuit (TCC)

Data collection

Data collection is performed with the pressure gauge specified in Table 1, according to the steps described in section 2.1. The data acquisition process for each stage is described below:

Engine break-in.

- Taking the pressures in the cold front and rear tires.
- Exit the karting to the circuit with cold tires.
- Complete the circuit with the power unit at low revolutions.
- Pressure measurement of hot front and rear tires.
- Go Karting to the circuit with hot tires.
- Complete the circuit with the power unit under the same parameters.

Free Tests.

- Taking the pressures in the cold front and rear tires.
- Exit the karting to the circuit with cold tires.
- Complete the circuit in the time established by the organizers of the Austral Karting Championship.
- Pressure measurement of hot front and rear tires.
- Go Karting to the circuit with hot tires.
- Complete the circuit in the time established by the organizers of the Austral Karting Championship.

Competition

- Taking the pressures in the cold front and rear tires.
- Exit the karting to the circuit with cold tires.
- Complete the circuit in the shortest time possible.
- Pressure measurement of hot front and rear tires.
- Go Karting to the circuit with hot tires.
- Complete in the shortest time possible.

Factor levels from the Box Behnken method

The Box Behnken method is a 2k factorial design that optimizes a process through an experimental design that establishes the most influential factors in the response variable.

For the application of this method, the levels of the input variables must be established, which are detailed in Tables 3 – 6, these are raised considering the tire pressure limits and the resulting weights between the Kart and the pilot.

Table 3
Levels of factors for the engine break-in

Factors	Levels		
	Minimum	Neutral	Maximum
PNDC	9 PSI	10.75 PSI	12.5 PSI
PNDF	9 PSI	10.75 PSI	12.5 PSI
PNTC	10.5 PSI	11.5 PSI	12.5 PSI
PNTF	11 PSI	11.75 PSI	12.5 PSI

Table 4
Levels of factors for free tests

Factors	Levels		
	Minimum	Neutral	Maximum
PNDC	9 PSI	10 PSI	11 PSI
PNDF	9 PSI	10.75 PSI	12.5 PSI
PNTC	9 PSI	10 PSI	11 PSI
PNTF	9 PSI	10.75 PSI	12.5 PSI

Table 5
Levels of factors for career

Factors	Levels		
	Minimum	Neutral	Maximum
PNDC	9 PSI	10.75 PSI	12.5 PSI
PNDF	9 PSI	10.75 PSI	12.5 PSI
PNTC	9 PSI	10.75 PSI	12.5 PSI
PNTF	9 PSI	10.75 PSI	12.5 PSI

Table 6
Factor levels for total driver and kart weights.

Factors	Levels		
	Minimum	Neutral	Maximum
Pilot 1	166.3kg	181.3kg	196.3kg

Results and Discussion

The results are presented according to the analysis criteria described above in section 2.1 and are analyzed under the criteria of the Pareto diagram and the analysis of variance graphs (ANOVA), with this a characteristic equation is established to subsequently obtain a response surface, which makes it possible to identify the optimum values of tire pressure, both cold and hot, with the aim of achieving a shorter lap time.

Engine break-in

In order to evaluate each factor and its interaction, Figure 2 shows the normal probability plot of the standardized factors for experimentation.

Figure 2
Normal Probability (Engine break-in)
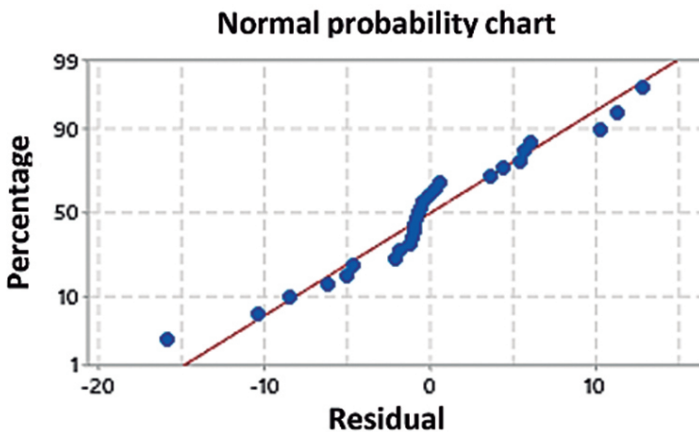
As can be seen in Figure 2, the behavior of the data taken is adjusted to the straight line of the normal probability graph, without having any atypical value that affects the results.

Figure 3 shows the Pareto diagram, in which it can be seen that the most influential variables for the TCC are A, C, B; the same ones that represent the PNTC, PNTF, PNDF respectively. These variables are analyzed with a pvalue ≤ 0.05, so considering that the pvalue is the value that defines the probability of accepting a null or alternative hypothesis, for this experiment the alternative hypothesis is accepted given that variables A, C and B statistically they are found with a value lower than 0.05.

Figure 3
Pareto chart (Engine break-in)
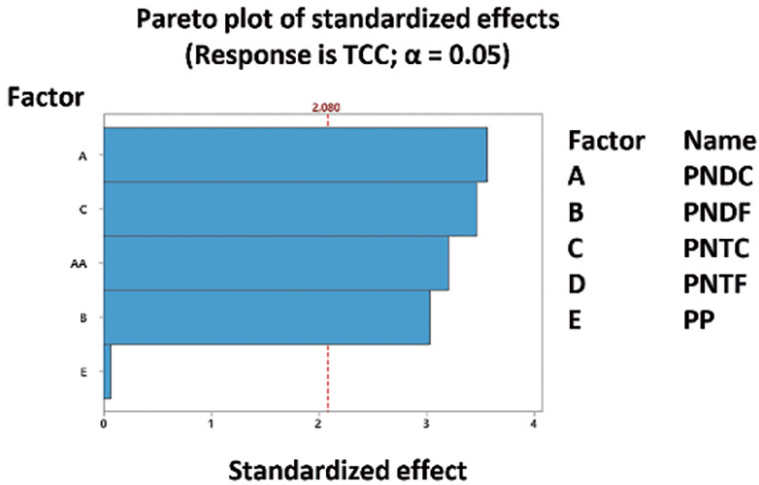
Next, a single-factor ANOVA analysis is performed to corroborate the influence of the variables (PNDC, PNTC and PNDF) with respect to TCC.

Figure 4
a) ANOVA TCC vs PNDC analysis, b) ANOVA TCC
vs PNTC analysis, c) ANOVA TCC vs PNDF analysis
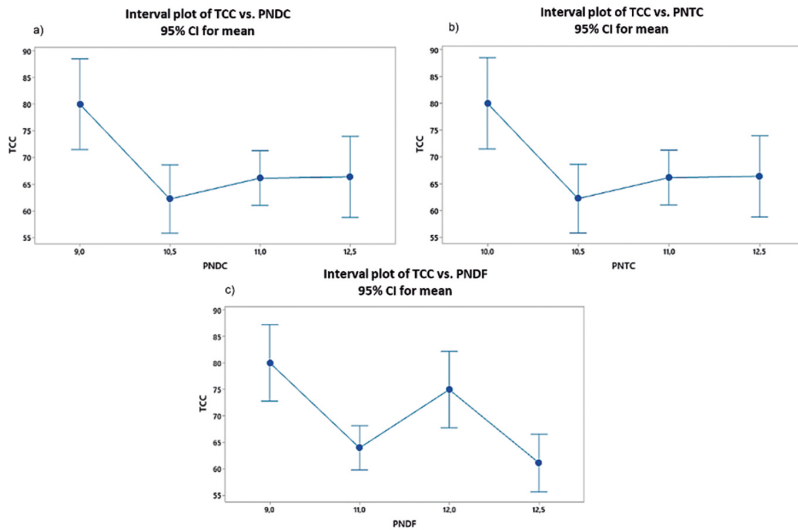
Figure 4 a) and b), show that the influencing variables must have a pressure close to 10.5 PSI, due to the time to complete the circuit is lower at these points. However, in Figure 4 c) the influencing variable must contain a pressure close to or equal to 11 PSI to reduce the lap time.

From the Box Behcken methodology applied to the engine settlement parameter, equation 1 is obtained, which determines the TCC, depending on the input variables (tire pressure), in addition, the graphs of the response surfaces were generated, such as It can be seen in Figure 5 a) and b).

$$TCC = -6568 + 971PNDC - 2781PNDF + 241.7PNTC + 0.010PP - 52.7PNDC * PNDC \quad (1)$$

Figure 5
a) Response surface TCC vs PNDF – PNTC, b) Response surface TCC vs PNDC – PNTC

a)   TCC vs. PNTC - PNDF surface plot
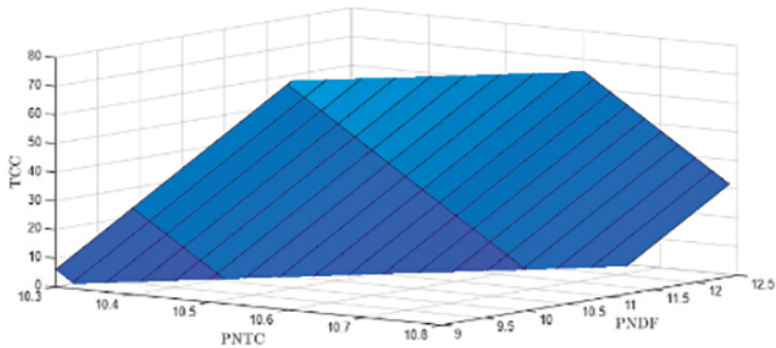
b)   Response surface plot TCC vs. PNDC - PNTC
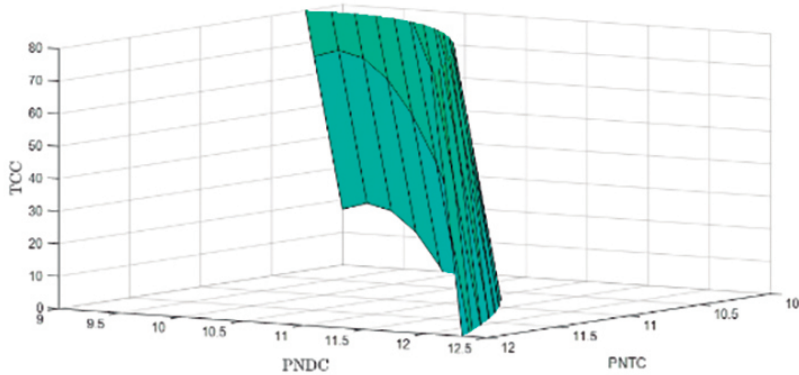
The response surface figures help us determine under what value of the input variable it is possible to obtain a shorter time to complete the circuit, as can be seen in Figure 5a) the optimal pressure to have a shorter time to complete the circuit by configuring the PNDF and

PNTC variables at the same time ranges between 9Psi – 10Psi and 10Psi – 10.5Psi. On the other hand, the optimal pressure settings with the input variables PNDC and PNTC are 12Psi – 12.5Psi and 11.5Psi – 12Psi.

Free tests

As can be seen in Figure 6, there is no statistical aberration, therefore, the results presented fit the straight line.

Figure 6
Normal Probability Plot (Free Trials)
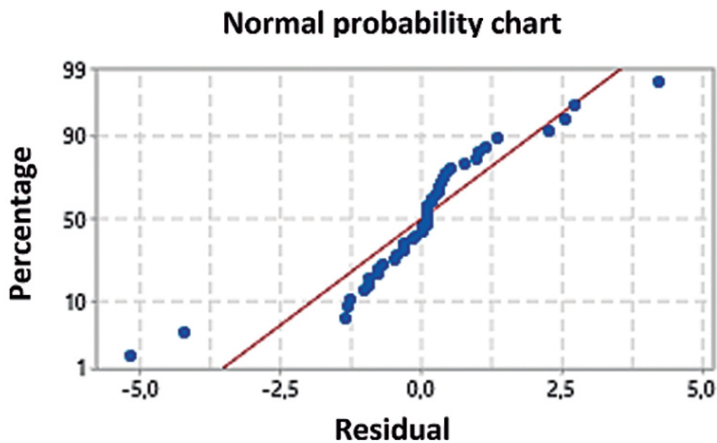
Figure 7 shows the Pareto diagram, the variables that influence the TCC are: A, B, C; the same ones that represent PNDC, PNDF, PNTC respectively. Because the input variables A, B, C contain a pvalue less than 0.05, an alternative hypothesis is accepted, given that these are highly influential with respect to the output variable.

Figure 7
Pareto diagram (free tests)

Pareto plot of standardized effects
(Response is TCC; α = 0.05)
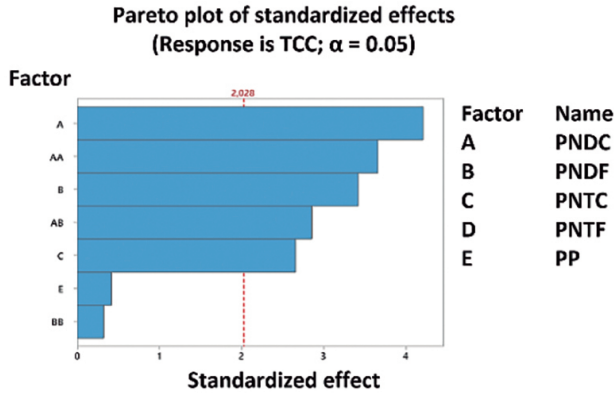
Figure 8 a) and b), shows that having a pressure close to 10 PSI, the time to complete the circuit is shorter compared to the other pressures located in the graphs.

Figure 8
a) ANOVA analysis TCC vs PNDC (free tests), b) ANOVA analysis
TCC vs PNDF (free tests), c) ANOVA TCC vs PNTC analysis (free tests)

b) Interval plot of TCC vs. PNDF
95% CI for mean

c) Interval plot of TCC vs. PP
95% CI for mean
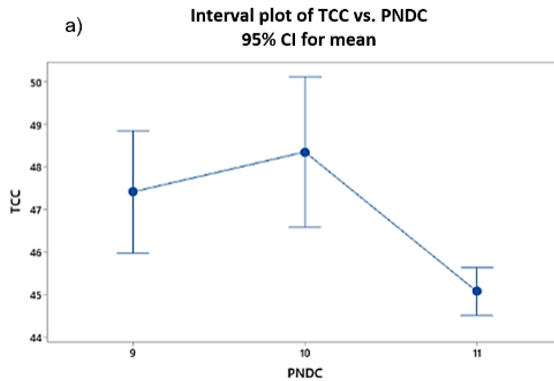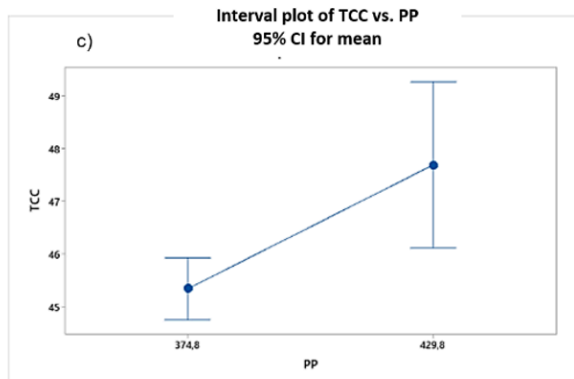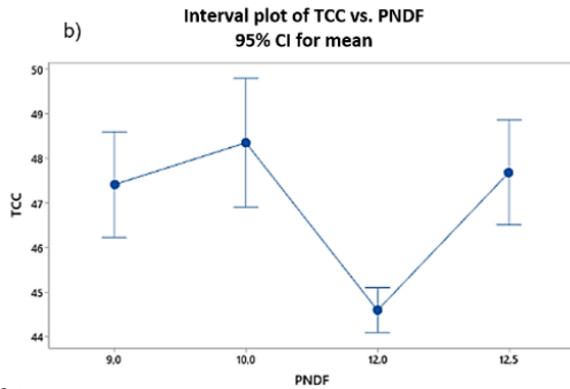
However, to minimize the completion time of the circuit under the influencing variable PNTC, the tire pressure should range between 10 - 9 Psi, as shown in Figure 8 c).

Figure 9
a) Surface plot TCC vs PNTC – PNDF (free tests), b) Response surface plot TCC vs PNDC – PNTC (free trials)

a)   TCC vs. PNTC - PNDF surface plot
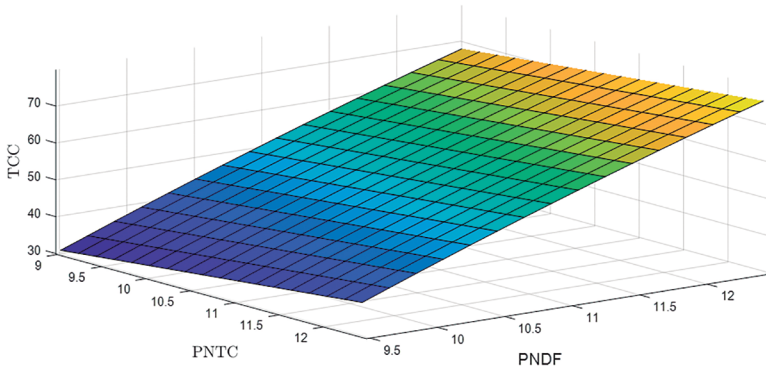
b)   Response surface plot TCC vs. PNDC - PNTC
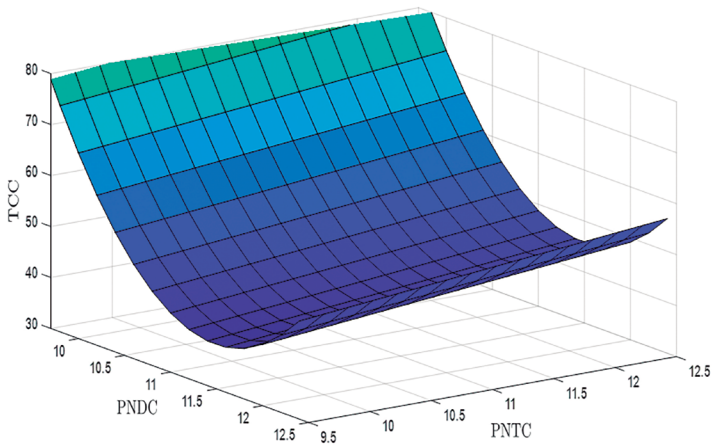
According to the response surfaces represented in Figures 9 a) and b), the input variables have a greater influence on the output vari-

able (TCC), considering that the response surface has an unstable behavior. For this study parameter, the optimal pressure values to reduce the time per lap are between 9.5Psi – 10Psi for the cold front tires and 9Psi – 9.5Psi for the hot rear tires, what is mentioned can be seen in Figure 9 a). However, to reduce the time to complete a circuit with the PNDC and PNTC input variables, the pressures range between 11Psi – 11.5Psi and 9.5 Psi – 10 Psi, this characteristic is observed in Figure 9 b).

The response surfaces were plotted from equation (2).

$$TV = -116 - 137.7PNDC + 172.5PNDF + 2.385PNTC - 0.0133PP + 12.62PNDC * PNDC - 0.48PNDF * PNDF - 14.11PNDC * PNDF \quad (2)$$

Competition

Following the same dynamics of the previous analyses, Figure 10 shows the normal probability graph of the data taken for this study parameter. The data have a normal behavior with respect to the reference line of the percentage vs residue, for which the values taken can be considered for the study.

Figure 10
Normal Probability Plot (Competition)
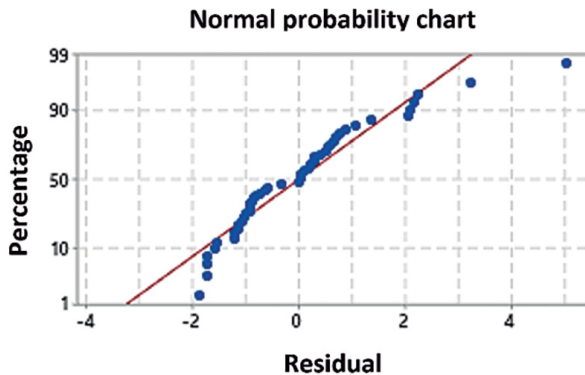
To identify the influential input variables in the competition analysis, the Pareto criterion is considered (Figure 11). For this research parameter, the most influential variables in the TCC are the weight of the driver, cold front tire pressure, and hot front tire pressure.

Figure 11
Pareto's chart (Competition)
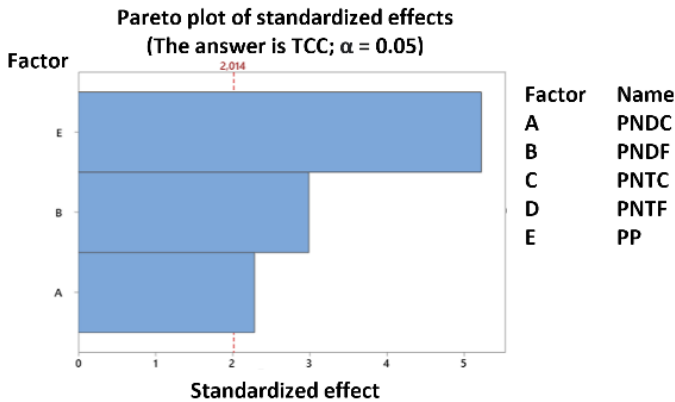
The Pareto Diagram criterion is corroborated with Figures 12 a) and c), where an ANOVA analysis of the collected data is presented, in these graphs the influence of the input variables on TCC is identified. According to Figure 12 a) with a pressure of 11 Psi in the hot front tires, the TCC can be decreased, therefore, Figure 12 b), is interpreted that for an optimal value of time the pressure of the cold front tires should be calibrated at 12 Psi. Undoubtedly, the total weight of the karting (Driver + vehicle) is an influential variable, as identified in Figure 12 c), an adequate weight for a better competition time would be 374.8 kg, in practice this value is impossible to achieve, therefore, the ideal weight should be close to this study value.

Figure 12
a) ANOVA analysis TCC vs PNDC (competition), b) ANOVA analysis TCC vs PNDF (competition), c) ANOVA analysis TCC vs PP (competition)
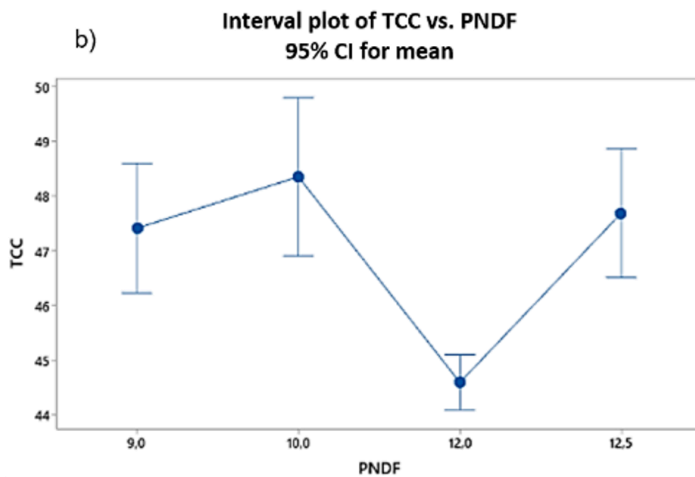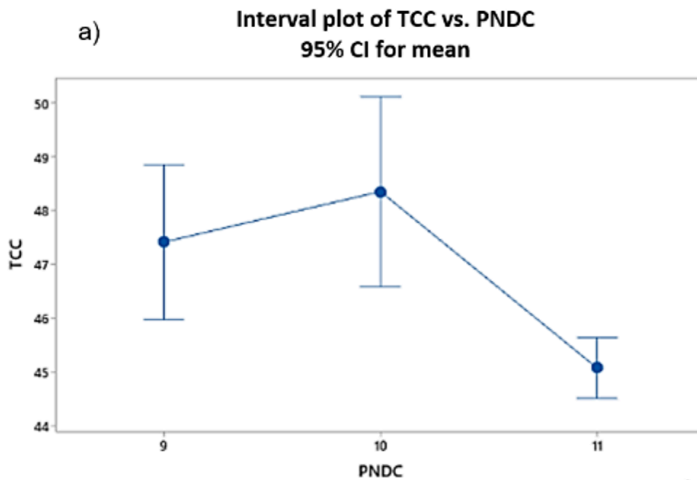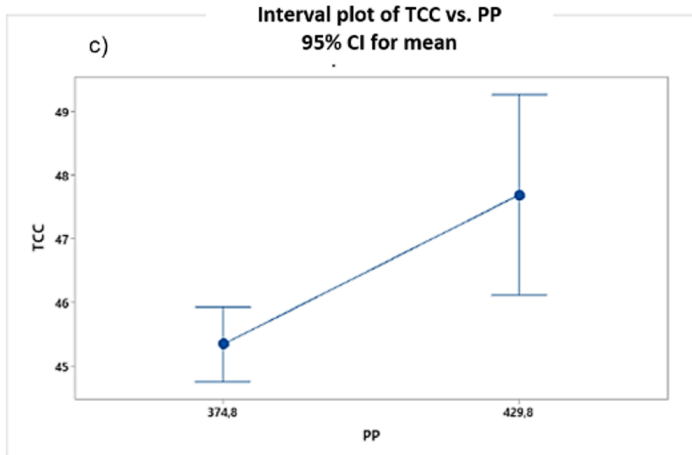
Figures 13 and 14 represent the response surfaces of the input variables that have a greater influence on the output variable (TCC). For this study parameter, the optimum pressure values to reduce the time per lap are between 12Psi – 12.5Psi for cold front tires and 9Psi – 9.5Psi for hot front tires, at these pressures the must combine with a total weight close to 370 kg for good performance in competition.

Fiure 13
Surface plot TCC vs PNDF-PP (competition)
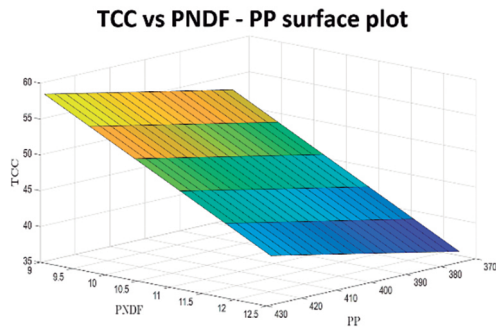
Figure 14
Surface plot TCC vs PNDC - PP (competition)
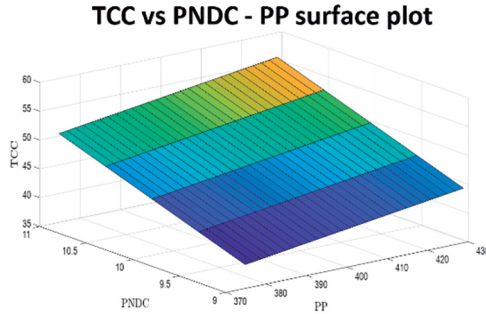
$$TCC = 1.8 + 5.64PNDC - 4.70PNDC + 0.0990PP \quad (3)$$

In equation 3, the ranges of the input variables can be changed to identify the optimal values and decrease the competition times.

Conclusions

- Prior to the application of the Box Behnken method, the behavior of the data collected in the experimentation must be analyzed. In this research, this analysis is carried out with the normal probability graph of the percentage vs the residual (Figures 2, 6 and 10)., where, in all the analyses, the data are adjusted to the reference line established for an acceptance of the experimentation.
- The equations (1, 2 and 3) and the surface graphs (Figures 5a), 5b), 9a), 9b), 13 and 14) established in this investigation allow Generate an analysis with mathematical criteria to establish tire pressure calibrations and obtain better performance in karting competitions.
- In the engine settlement stage, it is concluded that the input variables PNDC, PNTC and PNDF are highly influential for the

output variable (TCC), what has been said is corroborated with the Pareto diagram of Figure 3, in addition a study of each factor with the ANOVA methodology, which gives us that in order to have a shorter time to complete a circuit, a pressure of 10.5 Psi, 10.5 Psi and 11 Psi must be present for the PNDC, PNTC and PNDF variables, respectively.

To improve the performance of karting in free tests, the combination of pressure adjustment in the PNDF, PNDC and PNTC variables should be considered. In this aspect, if a pressure setting is established between PNDF and PNTC the optimal pressures are between 9.5Psi – 10Psi and 9Psi – 9.5Psi respectively. On the contrary, when setting the pressure between PNDC and PNTC the optimal pressures vary to 11Psi – 11.5Psi and 9.5 Psi – 10 Psi respectively.

- In competition the most important variables for the optimization of the karting are the pressure in the hot and cold front tires, with pressures between 12Psi - 12.5Psi and 9Psi - 9.5Psi respectively. In addition, the total weight of the karting (driver + chassis) is one of the most influential variables and according to the analysis an ideal weight for competition would be 370 kg, however, in practice there are limitations to reach this exact weight, therefore, in this study this value remains as a reference.

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Application of Supervised Descriptive Rule Discovery Methods: Review and Architecture

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Abstract

An autopsy is a recognized procedure for achieving continuous improvement in the quality of medical work despite its worldwide decline, while data mining is the process of finding patterns, anomalies, or correlations between data in a data set. Supervised descriptive

rule discovery (SDRD) brings together the two types of tasks that exist in data mining, i.e., both descriptive and predictive areas. The objective is to describe data with respect to a property of interest. In this paper, we provide the results of the analysis of 39 articles related to SDRD to select the adequate techniques and technologies to design the architecture of a module for the comparison of medical opinions related to the decrease ot autopsies in Mexican hospitals. In this way, we seek to address the current problem of the decrease in the number of autopsies in the country, which resulted in the interest of the director of the Pathology area of the Hospital Regional of Río Blanco (H.R.R.B.) in designing and applying a survey to physicians to know the causes of this autopsy decline to take actions that increase this study. The SDRD works were analyzed following a methodology wtih three stages: search, selection and analysis, to conclude that the technique that provides the ability to perform all the features proposed in this work is subgroup discovery (SD), therefore, the proposed module architecture was designed considering SD to compare the results obtained in the H.R.R.B. with those of other hospitals.

Keywords

Introduction

An autopsy is a recognized procedure to achieve continuous improvement in the quality of medical work. It is where the pathology specialist who performs it examines a corpse to determine the causes of death, it is an orderly and thorough process. The practice of such a procedure makes an important contribution to the medical knowledge and learning of physicians in training [1].

Due to the decrease in the number of autopsies performed at the Hospital Regional of Río Blanco (H.R.R.B.), the director of the hospital's Pathology area prepared a survey and applied it to the medical staff of his hospital to find out the causes, reasons, and circumstances of this decrease. A system for analyzing these surveys has been developed in earlier work [2]. The system uses descriptive (association) and predictive (classification) data mining tasks. The system revealed that the main reasons for not performing autopsies at the H.R.R.B. are known underlying disease, refusal of family members, disinterest, social factors, fear of demand, cultural issues, religious issues, lack of indication, lack of human resources, and lack of material resources.

Subsequently, a module for comparing medical opinions from various hospitals was added to the system [1]. The module uses Emerging Pattern Mining, a Supervised Descriptive Rule Discovery technique. The main problem of the system is that the generated models are presented in the form of rules, which have to be evaluated by the specialist, when the number of rules obtained increases, the complexity of the evaluation also augments.

The SDRD concept is a combination of the two types of tasks that exist in data mining, i.e. descriptive and predictive tasks. The purpose is to describe data related to a target property. The techniques found in the SDRD are subgroup discovery, emerging patterns, and contrast sets [3].

In this context, the contribution of this paper is two-fold: 1) A review of 39 articles on SDRD techniques was carried out, and 2) A module architecture was proposed to facilitate the comparison of the results of the surveys applied to physicians in Mexican hospitals.

The main benefit expected from the development of this module is to use other SDRD techniques, specifically SD, to compare the reasons why autopsies are not performed in other hospitals, to determine if they are the same as at H.R.R.B. so that the Pathology Department staff can take measures to increase the number of autopsies performed at the hospital. In addition, the selected techniques are intended to allow better data visualization to easily distinguish differences in the medical opinions of the different hospitals.

This article is organized as follows: section 2 presents the analysis methodology applied, section 3 describes the architecture and the solution proposed for this development, and finally, section 4 describes the conclusions obtained based on the analysis and future work.

Methodology of analysis

The study and analysis of advanced SDRD techniques were based on 39 articles that were downloaded from the main digital Computer

Science libraries (IEEE Xplore, ACM digital library, SpringerLink, ScienceDirect, among others). Article selection was based on the technique used: Subgroup Discovery or Contrast Sets. Only articles published in English in journals or conference proceedings during the past five years (2018-2022) were eligible.

Subsequently, the articles were analyzed and compared against certain parameters, for example, visualization, comparison of opinions, focusing on the medical field, to name a few. Most of these opt for the use of visualization, and the use of subgroup discovery, however, very few of them are based on the comparison of opinions or focus on the medical field. Fig. 1 shows the analysis methodology used for the study of the works.

Figure 1
Methodology of analysis
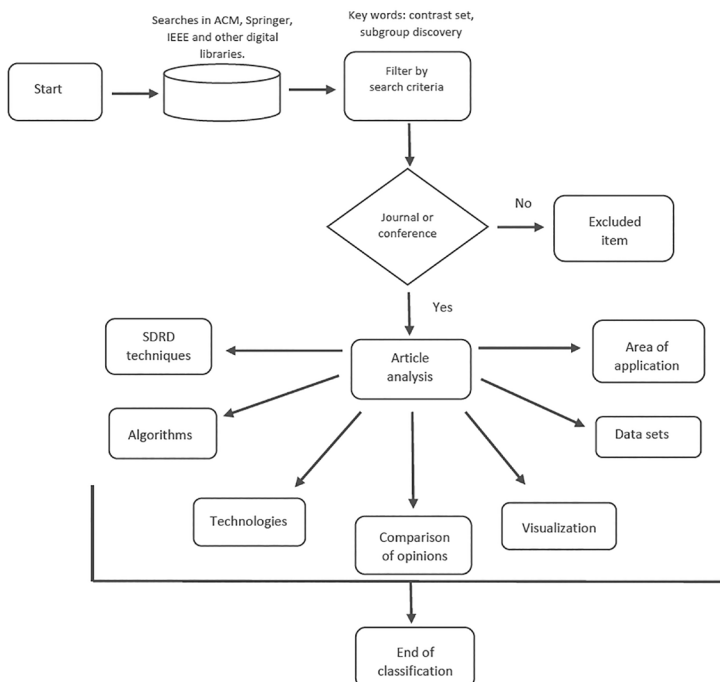
Table 1 shows the comparative table of the articles analyzed for which the following criteria were taken into account: A) Comparison of opinions, B) Use of visualization, C) Contrast sets, D) Subgroup discovery, and E) Focus on the medical area.

Table 1
Comparative analysis of the SDRD works

Work	A	B	C	D	E
Carmona et al. [3]		x	x	x	
Centeio et al. [4]				x	
Lopez-Martinez-Carrasco et al. [5]		x		x	x
Lucas et al. [6]		x		x	
Costa et al. [7]				x	
Wang and Rudin [8]		x		x	
Atzmueller [9]				x	
Al-Taie et al. [10]		x		x	x
Luna et al. [11]				x	
Mattos et al. [12]		x		x	x
Park et al. [13]				x	x
Foppa and Ghiringhelli [14]		x		x	
Hendrickson et al. [15]		x		x	
Helal et al. [16]				x	
de Leeuw et al. [17]	x			x	
Esnault et al. [18]				x	x
Hammal et al. [19]		x		x	
Proença et al. [20]				x	
Luna et al. [21]		x		x	
Kiefer et al. [22]		x		x	
Cervantes et al. [23]		x	x		
Valdivia et al. [24]				x	

Remil et al. [25]		x		x	
Liu et al. [26]		x	x	x	x
Loyola-Gonzalez et al. [27]		x	x		
Loyola-González et al. [28]		x	x		
Varlamis [29]		x	x		x
Kong et al. [30]		x	x		
Cañete-Sifuentes et al. [31]		x	x		x
Tallon et al. [32]			x		x
Loyola-González et al. [33]		x	x		
Qian et al. [34]		x	x		
Li et al. [35]		x	x		
Al-Taie et al. [36]		x	x		x
Duan et al. [37]	x	x	x		
Alipourchavary et al. [38]			x		
Luna et al. [39]				x	
Loyola-González et al. [40]		x	x		
Jahan et al. [41]	x	x	x		x

After studying the 39 articles, it was concluded that only 28% (11) of them focused on the medical area and none of these eleven works considered the comparison of opinions. In addition, most of the SDRD works (62%) opted for the use of subgroup discovery as a data mining technique. For these reasons, this paper proposes an architecture of a module that uses subgroup discovery to compare medical opinions on the decrease of autopsies performed in Mexican hospitals.

Classification of analyzed works

Year of publication. Figure 2 shows the number of articles published annually, separated by the technique: Discovery of Subgroups (SD) and Contrast Sets (CS). Of these, 15 articles are related to CS, 22 focus on SD, and 2 consider both techniques. The graph indicates that there is a

higher number of SD publications in more years (2018, 2021, and 2022), while there is the same number of CS works between 2019 to 2020.

Figure 2
Publications by year
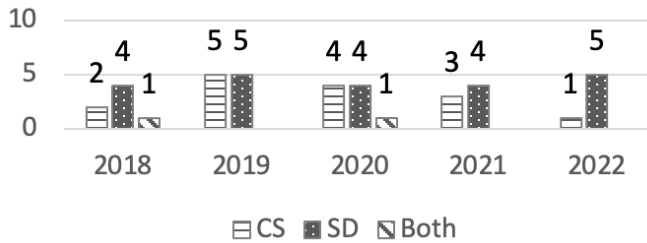
Publisher. Fig. 3 depicts that the publishers with the most publications of the subgroup discovery were Springer and others; whereas for contrast sets, Springer and IEEE.

Figure 3
Papers by publisher.
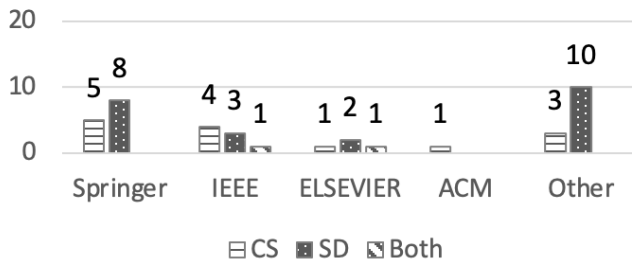
Data Mining Tool. Fig. 4 exhibits the tools used in the DSRD works, where it can be seen that the CS approaches utilized WEKA (e.g., [28], [31], [40]), while most of the SD techniques used VIKAMINE ([9], [15], [16]).

Algorithms. Fig. 5 shows the algorithms used in the analyzed papers, the most frequent algorithms for DSRD applications were: SD-Map* [9], Top-k, SD-Map, Single Shot Detector (SSD), Pattern-based Classifier for Class Imbalance Problem (PBC4cip), and Others, of which the most frequent are PBC4cip and SD-MAP.

Figure 4
Technologies used in the analyzed works.
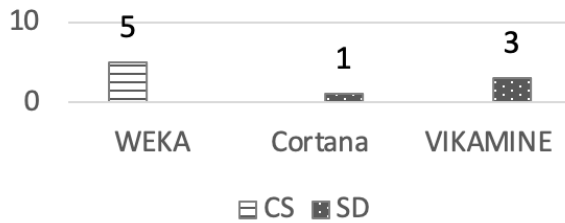
Figure 5
Algorithms used in the DSRD approaches.
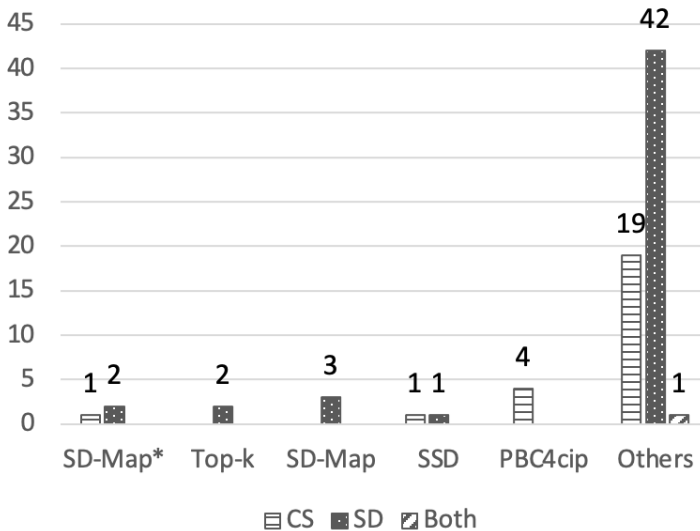
Programming languages. Fig. 6 shows the programming languages most commonly used in the reviewed papers. The most popular language for contrast sets was Java, while for subgroup discovery it was Python.

Figure 6
Programming languages used in the analyzed papers.
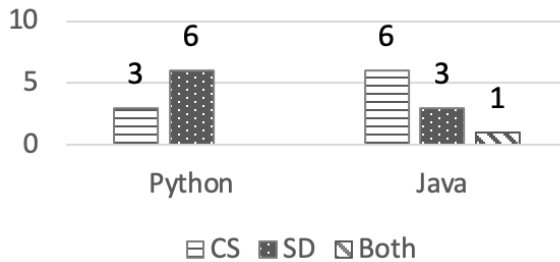
Comparison of opinions. Works that base their research and/ or development on opinion comparison are shown in Fig. 7. As can be seen, the use of opinion comparisons is infrequent in the articles analyzed, as only 3 [17, 37, 41] out of 39 articles consider them.

Figure 7
Comparison of opinions in SDRD works.
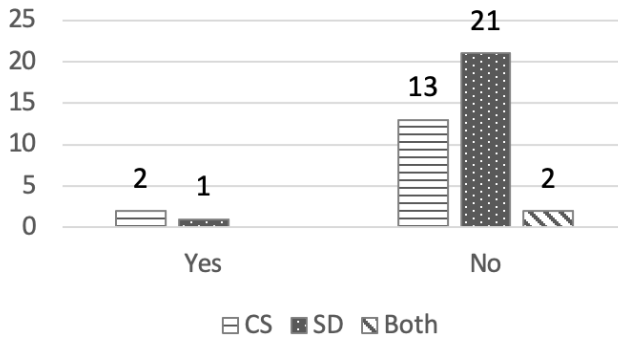
Visualization. As can be seen in Fig. 8, the graph shows that 26 of the 39 papers analyzed make use of some visualization method to improve the interpretation and analysis of the results obtained.

Figure 8
Use of visualization in the SDRD applications.
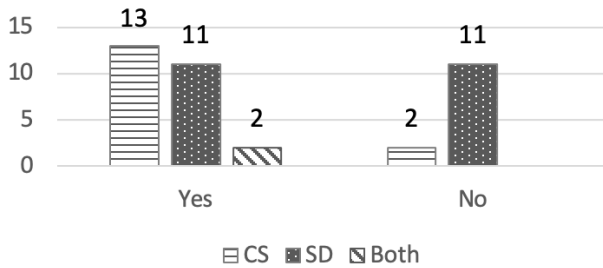
Data sets. Fig. 9 shows the places where the data were obtained and their frequency in the cited works, among which repositories such as Knowledge Extraction Based On Evolutionary Learning (KEEL), The Cancer Genome Atlas (TCGA), UCI Machine Learning Repository, Surveillance Epidemiology, and End Results Program (SEER), TripAdvisor, and Others, were found.

Figure 9
Data collection in SDRD works.
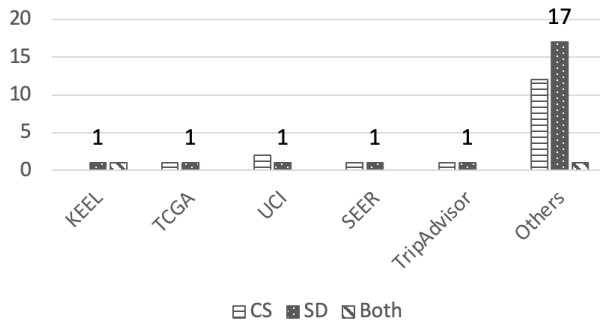
Area of application. Fig. 10 shows the application areas of the 39 analyzed papers, obtaining as a result that the areas of greatest application were: Medical area and Research, e.g., [12, 26].

Figure 10
Research areas of SDRD applications.
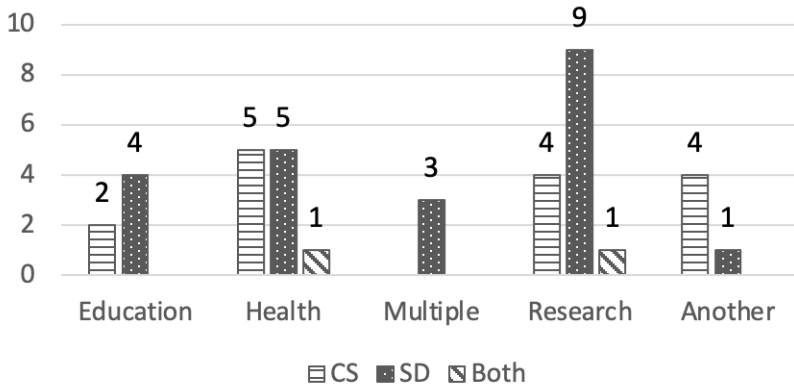
In the following section, the description of the proposed architecture is presented.

Architecture

In this section, we present the architecture of a Subgroup Discovery module for the comparison of medical opinions about the decrease of autopsies in Mexican hospitals. Figure 11 shows the proposed solution scheme for this architecture.

Figure 11
Solution outline.
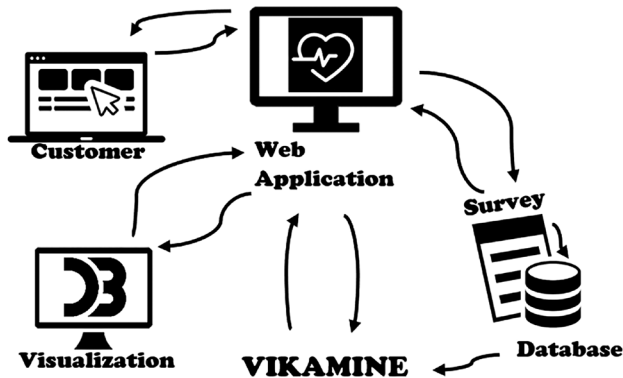
As Figure 11 shows the user is expected to add and visualize the results of the surveys to the database through a Web application, where the algorithms provided by VIKAMINE are expected to generate the models based on such data and present them to the user in a graphical way for a better and quick understanding for its analysis. The new system module for survey analysis is intended to be developed according to the UWE (*UML Web Engineering*) methodology since it adapts to the characteristics of Web systems, has views graphically represented through UML (*Unified Modeling Language*) diagrams, is easy to learn, and allows for quick correction of bugs and problems encountered throughout the Web system development life cycle. In addition, for the programming language, we intend to use Java, because it is a fast language (compared to other alternatives for development like Python), therefore, the IDE (*Integrated Development Environment*) analyzed with the most optimal features for this procedure is NetBeans because, unlike Eclipse (for example), the project structure in NetBeans provides a much clearer view of large applications, from the DBMS (Database Management System) we intend to use PostgreSQL since it has support for Java, high reliability and robustness, extensive documentation, free installation and use, it is multiplatform, to mention some of its most important characteristics.

JavaServer Faces (JSF) is intended to be used as a development framework because it provides a clear separation between behavior and presentation, facilitates the construction and maintenance of Web applications, and provides a clear separation between behavior and presentation. As a data mining tool, VIKAMINE allows the use of multiple data types, features a generic subgroup discovery algorithm that can be configured in many ways to implement various forms of local pattern discovery, is Java-based, and is freely licensed, among other features.

As a data mining methodology, it is intended to use KDD (*Knowledge Discovery in Databases*) as this is an iterative and interactive process (Fig. 12 shows this process in greater detail), and is in rapid development, Finally, we will use D3.js data visualization library because it is a JavaScript library suitable for manipulating documents without the need to be coupled to a proprietary framework, thus facilitating the interpretation of the results obtained by the pathologists.

Fig. 12 shows the KDD process that is intended to be used as a methodology for data mining adapted to this work:

Figure 12
KDD Process.
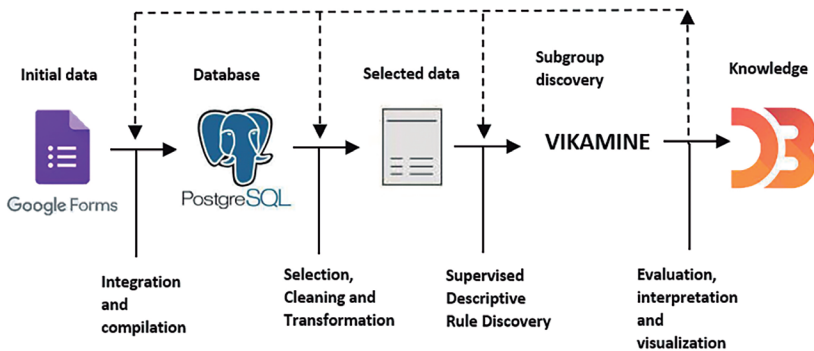
KDD is a methodology proposed in 1996, it is an interactive process consisting of five stages [41], each stage is described below considering the analysis of the medical opinions proposed in this paper:

1. Selection: the algorithms that could be used to compare medical opinions will be analyzed and the results of the surveys will be collected utilizing Google Forms.
2. Preprocessing: the target data set (selected data) will be obtained/created.
3. Transformation: basic operations will be applied, including noise elimination, and empty fields, to mention a few, the main objective of this stage is to reduce dimensionality.
4. Data Mining: Subgroup discovery algorithms will be applied using the VIKAMINE data mining tool and looking for models of interest in the dataset.
5. Implementation: an interpretation and evaluation of the results will be carried out using the D3 visualization library.

The proposed architecture for the new Web application module is shown in Fig. 13. The proposed architecture for the new system module is based on one of the most widely used models for web application development, called MVC (Model-View-Controller). The functionality of each component is briefly explained below:

Figure 13
Proposed architecture.
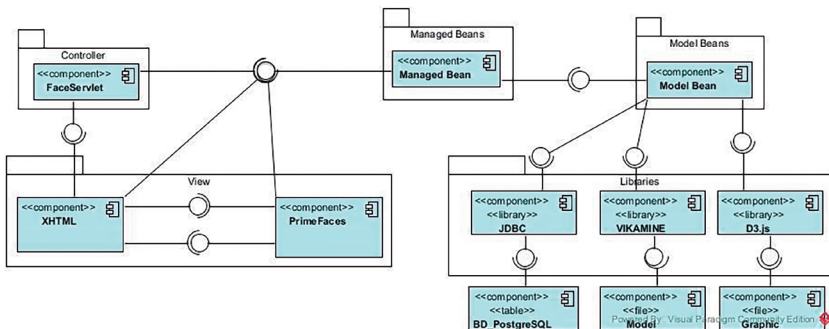
- **FaceServlet:** This component represents the elements provided by the FaceServlet libraries.
- **Managed Beans:** This component includes the classes necessary for the control and management of the system logic.
- **Model Beans:** This component contains the classes required for the creation of the models within the system.
- **XHTML:** The function of this component is to provide the ability to create/support XML files.
- **PrimeFaces:** This component represents the elements offered by the PrimeFaces library.
- **JDBC:** The function of this component is to provide access to the database management system, employing the necessary drivers,.
- **BD_PostgreSQL:** Consists of the database managment system to be used.
- **VIKAMINE:** This component provides the necessary plugins for the use and creation of models using the VIKAMINE data mining tool.
- **Model:** This component is responsible for generating the models of the data already processed and obtained from the data sets.
- **D3.js:** This component provides the necessary plugins for the use and creation of the models in a graphical way by using the D3 visualization library.
- **Graphic:** This component presents as a final result the graphs to visualize, interpret and evaluate the results obtained.

Conclusions and future work

After analyzing the 39 SDRD works, it was concluded that supervised descriptive rule discovery techniques are used to solve problems in different areas and it was observed that subgroup discovery is used in most of these applications. Nevertheless, it was found that SDRD approaches that focus on the medical area and opinion comparison are scarce, therefore, none of the reviewed methods addresses the five criteria selected for the study of the analyzed papers. Therefore, with

the new proposed architecture, we intend to develop a module for the comparison of medical opinions on the decrease of autopsies, using the DS to address the problem that pathologists have in understanding the results obtained, thus providing an easier and faster interpretation of these results. It is expected that this will contribute to the decisión-making of the corresponding areas of the hospitals to increase the number of autopsies.

In the future, the following activities will be performed: Implementation of the survey using the Google Forms platform; design of the new system module; insert the data obtained from the surveys into a database, the database management system will be PostgreSQL; perform the coding of the new system module to compare the data sets using SD and generate the results using the D3.js data visualization library, and finally, validate the newly developed module using a case study.

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Identification of Potential Fishing Areas through Daily Analysis of Physical and Biogeochemical Variables of the Ocean

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Abstract

Illegal and unregulated fishing is a grave issue that is altering the global marine ecosystem. Ecuador, given its geographical situation and the nutrients transported by the currents circulating through its waters, also suffers from over-fishing, especially around the Galapagos Islands. For this reason, given the large marine territory under its possession, great national efforts are required to exercise control and sovereignty over its national waters. This research presents a methodology through which the Ecuador Navy can daily identify prime fishing areas, prioritizing its guarding, considering fishing events from previous years as well as physical, chemical and biological values of geographical areas

where illegal fishing activities took place. To this end, we have used datasets belonging to Copernicus Space Programme and the Global Fishing Watch organization. We have also made use of statistical tools such as kernel density estimation, to estimate the heat maps that allow identifying the gravity centres of the different potential fishing areas.

Keywords

Illegal, Unreported and Unregulated Fishing, Kernel Density Estimation, Potential Fishing Areas.

Introduction

The world population is growing rapidly, it has increased from 2.6 billion to 7.7 billion people since the Second World War, with China (1,449 million) and India (1,390 million) being the countries with the greatest demographic expansion, representing 19% and 18% of the world population, respectively [20]. Therefore, the sea resources are fundamental for the provision of the protein necessary for the nutrition of human beings, being the exclusive right of the States to exploit for their benefit the resources available in their exclusive economic zones (EEZ). Outside these zones, the existing resources are freely available to the countries that require them and that is where the over exploitation of fishery resources begins, especially to satisfy the needs of the Asian countries.

Ecuador has a jurisdictional maritime space of 1'092,140.25 km2, in which it exercises sovereignty, control and exploitation of marine resources in a sustainable and rational manner [16]. This maritime territory is strongly influenced by a series of marine currents, which positively affect its biodiversity, as they distribute nutrients throughout the geographical space. Among the predominant currents are the cold Humboldt and the warm El Niño currents. There is also the Cronwell countercurrent in the Galapagos Archipelago, which distributes nutrients around the islands. The sea richness is however being threatened by illegal activities in and outside of jurisdictional maritime areas. Illegal fishing is mainly related to the capture of fish or shellfish that contravenes national and international laws and regulations on fishing in jurisdictional and non-jurisdictional waters [4].

For the control of high seas fisheries, Regional Fisheries Management Organizations (RFMOs) are in charge of managing high seas fisheries, especially migratory and straddling fish stocks. States that share common interests organize themselves to act jointly in actions related to stock control, catches, assessments, decisions and monitoring, although the action implementation is always responsibility of the flag State [13].

According to Article 56 of COVEMAR, the passage of foreign vessels through jurisdictional areas can be restricted. The legal tools to do so are similar to those used to restrict freedom of navigation in an area of high ecological sensitivity such as the Galapagos Islands, establishing environmental protection mechanisms. These mechanisms have legal support and international support from the Convention of the Law of the Sea, through the application of Paragraph 1, Article 73, which empowers the coastal State to search and detain fishing vessels that violate these laws, as well as, in the case of actions of pollution of the marine environment, the Convention provides for the search of the vessel that performs them, according to Paragraphs 3 and 6 of Article 220, Part XII.

It is worth mentioning that fishing vessels cross the oceans in search of fish stocks, making early detection very difficult if these vessels disconnect their VMS system, or if the concerned country does not have the support of satellite surveillance or the permanent support of aero-maritime scanning, so vessels are detected when they have reached the fishing point. For this reason, the problem to be solved is to determine whether it is feasible to predict potential fishing zones in the Galapagos Islands to provide information that will contribute to the protection and sustainable exploitation of fishery resources.

It is important to emphasize that illegal, unreported and unregulated fishing (IUU) has a serious impact on the sustainability of fisheries [17], since inaccurate catch data do not allow for correct assessments that contribute to the estimation of sustainable catches. It is difficult to estimate the damage caused by this type of fishing, since it is not easy to

quantify; however, IUU catches are in the order of 10-20% of commercial catches, depending on the species and location [7].

The Ecuadorian State, through the Ecuadorian Navy, carries out surveillance and monitoring of the jurisdictional maritime areas, for which it uses its airplanes and ships daily to identify national and foreign vessels. This motivated the development of a tool to determine, in real time, the potential fishing areas, taking as a reference past events of fishing activities, which served to determine the value that the ocean variables have taken in those points, to serve as a reference for the search of similar conditions in the ocean on the current day, in order to intensify patrolling in those areas.

This study first analysed the fishing effort around the jurisdictional maritime areas of Ecuador, taking as a reference the fishing activities in the year 2020. Each of the geographic points where fishing activities took place were identified and recorded, and then the physical and biogeochemical conditions of the ocean where fishing took place were identified. This information was analysed on a daily basis, in order to determine the pattern of behaviour of these variables on a monthly basis, which serve as a reference to look for similar conditions depending on the day being analysed. Using the kernel density estimation (KDE) tool, it was estimated the zones in which fishing activity were concentrated. This analysis is performed by grouping the oceanic variables into physical, chemical, biological and nutrients.

This paper is organized in 6 sections; the first one corresponds to the introduction. Section 2 is a brief review of the literature related to this research. Section 3 presents the study area and the data used. Section 4 presents the methodology used and the experiments to be performed. In section 5, the results are discussed and finally, in section 6, conclusions are presented.

Related Work

As indicated by Mateo Witt and Brendan Godley in their article "A Step Towards Seascape Scale Conservation: Using Vessel Monitoring Systems (VMS) to Map Fishing Activity", in order to conserve marine ecosystems it is necessary to understand in a holistic manner the behaviour of fishing fleets, to have sustainable fisheries, being necessary to develop spatial models that show their distribution, for which satellite monitoring systems are the fundamental tool to determine their behaviour patterns [21].

As fish stocks are depleted, fisheries management faces control challenges, especially due to the increase in illegal, unregulated and unreported fishing. This situation is further exacerbated for countries with island territories, forcing these countries to have the necessary resources to monitor and guard their territorial sea [3]. Similarly, oceanographic conditions are a predominant predictor during seasonal variation in fishing effort, where productivity, migration pattern and fish distribution are influenced by environmental changes in temperature, chlorophyll-a concentration, currents, salinity and wind [18].

Currently, satellite remote sensing (SRS) is a tool used for environmental monitoring of the marine ecosystem and for fisheries management. Satellite images of oceanographic variables, such as chlorophyll concentration (Chl-a) and sea surface temperature (SST), are a source of information to explain the environment, presence and abundance of fish. Currently, the data provided by the SRS are fundamental to understand the habitats of marine species and their relationship with oceanographic conditions [8].

For this reason, remote sensing methods can also play an important role in guiding fleets to optimal fishing grounds, which will lead to more efficient fishing effort, with a corresponding increase in economic benefits. However, this optimization will also affect the marine ecosystem, since it will cause an increase in pressure on marine re-

sources, which will lead fishing authorities to also seek ways to regulate the exploitation of resources, and it is important for States to carry out fisheries management by analysing the relationship between the biotic and abiotic factors of the sea that govern the species distribution in the marine ecosystem [1]. It should be mentioned that traditional methods that study the distribution of species do not have sufficient information compared to methods related to remote sensing, to efficiently manage fishery resources.

It is worth mentioning that Resolution 61/105 on 8 December 2006, adopted by the United Nations Convention General Assembly, about sustainable fisheries, highlights the importance of the long-term conservation, management and sustainable use of marine ecosystems and the obligations of States to cooperate to this end and to implement conservation and management measures related to overfishing, bycatch, pollution and protection of the marine environment. The resolution urges countries to record data on catches and fishing related activities related specially to straddling fish and highly migratory fish found inside and outside the exclusive economic zones of each country, as well as to commit to combating illegal, unreported and unregulated fishing and to adopt all necessary measures [11].

The kernel density estimation (KDE) is a non-parametric neighbour-based smoothing function that has been used in ecology to identify hot spots in vulnerable marine ecosystems (VME), i.e. areas of relatively high biomass/abundance. The KDE technique counts the number of samples in a given area and creates a field from these objects, whereas other techniques such as interpolation estimate data values based on other data and requires these to be continuous and normally distributed [12]. KDEs are more efficient estimators than histograms and do not depend on interval width and grid origin and deliver more uniform results, allowing to identify characteristics such as skewness and outliers [15]. Similarly, the information provided by satellite monitoring devices provides important information that allows determining the

distribution of marine fishing activities in order to evaluate fishing pressure, which through the use of techniques such as KDE allows quickly mapping the hot spots where there is greater activity [14].

Study Area and Data

Our research area is located in the insular (Galapagos Islands) and continental exclusive economic zone of Ecuador, whose limits fall between 6ºN and 6ºS and between 75ºW and 100ºW.

Figure 1
Study area division
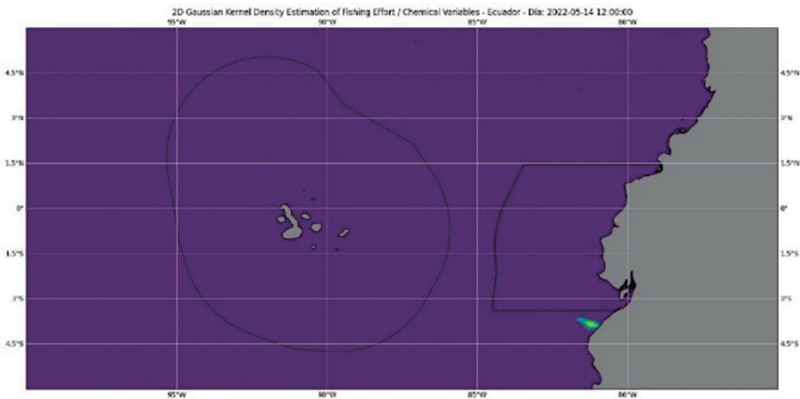
The data for this experiment comes from 2 datasets; the first one is provided by the Global Fishing Watch organization, which provides information on the transit of fishing vessels and location of fishing events. The records provided from the year 2020 have been used and its dataset is organized as follows (Table 1):

Table 1
Description of the fishing vessel positions
used in this experiment

Variable	Description	Unit
Date	Event date.	YYYY-MM-DD
cell_ll_lat	Latitude of the lower left corner of the grid cell.	decimal degrees
cell_ll_lon	Longitude of the lower left corner of the grid cell.	decimal degrees
mmsi	Maritime Mobile Service Identity, the identifier for AIS.	Real number
hours	Hours that the vessel was present in this grid cell on this day.	Hour
fishing_hours	Hours that the vessel was fishing in this grid cell on this day.	Hour

The second dataset comes from the database of the Copernicus European Space Program. It provides data of physical and biogeochemical oceanic variables for the year 2020. The data of physical variables come from database "Global Analysis Forecast-PHY- 001-024-TDS" [6], and data of biogeochemical variables come from database "Global Analysis Forecast-BIO-001-028-TDS" [5]. In Table 2, the variables used for this experiment are described.

During 2020, according to the database provided by Global Fishing Watch, 281,492 fishing vessel positions were recorded in the study area, of which 24,029 positions were categorized as fishing activities. To propose this methodology, we took into consideration only the fishing activity that took place during the month of June 2020, which corresponds to 6293 events.

Another additional consideration has been taken, which is related to the level of chlorophyll, as this indicator determines the presence of biomass in the ocean. During the month of June 2020, 2,489 fishing events were identified with a Chl-a level higher than 0.5 mg/m3; accord-

ing to Filatov *et al* [10], levels lower than 0.5 mg/m3 are considered low; for this reason, only fishing data above this value will be analyzed, to further guarantee the certainty of the prediction. It is worth mentioning that Chlorophyll-a ([Chl-a]) is used as an indicator of phytoplankton biomass [2], which is the most elementary level in the ocean food chain.

Table 2
Description of the physical and the biogeochemical variables

	Variable	Description	Unit
Biogeochemical variables	Chl	Total chlorophyll-a	mg/m3
	Fe	Dissolved iron	mmol/m3
	NO3	Nitrate	mmol/m3
	O2	Dissolved oxygen	mmol/m3
	pH	pH	
	PO4	Phosphate	mmol/m3
	Si	Dissolved silicate	mmol/m3
	SPCO2	Surface CO2	Pa
	Nppv	Net primary production	mmol/m3
	Phyc	Phytoplankton concentration in carbon	mmol/m3
Physical variables	ST	Sea water -40m temperature	ºC
	So	Salinity	1/e3
	Zos	Sea surface height	m
	Mlots	Mixed layer depth	m

Methodology and Experiments

Kernel Density Estimation

Heat maps allow to obtain a spatial interpretation of the data. These maps are intended to indicate the geographic clustering of a phenomenon, thus showing the event concentration at specific points and identifying possible trends. There are several probability density estima-

tion methods to identify hot spots, being the kernel density estimation method, also known as the Parzen-Rosenblatt window method, as one of the most popular. This method has been used in other experiments for the visualization of biological and statistical analysis [19].

Kernel density estimation, known as KDE, is a non-parametric technique to estimate the probability density function that, unlike the traditional method known as histogram, which shape is discontinuous and flat in each bin, the kernel density is smooth and represents a continuous variable [22]. The kernel estimate of f(x) and is defined as:

$$f(x) = \frac{1}{nh} \sum K\left(\frac{x - Xi}{h}\right) \qquad (1)$$

Where h is the bandwidth, called smoothing parameter, and K is the kernel, a non-negative function that must satisfy the following:

$$K(x) \geq 0 \ \ for \ all \ x \in R$$
$$\int_0^R K(x)dx = 1 \qquad (2)$$

There are some kernel functions which are commonly used, such as Epanechnikov, biweight, triangular, Gaussian, rectangular and others. In this case, the Gaussian function has been used since its estimate is more symmetric and smoother. It is represented by the following expression:

$$K(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \qquad (3)$$

Experiments

Firstly, a spatial and temporal analysis of the distribution of fishing events from 2017 to 2020 was carried out, whereby it was deter-

mined that these events do not present the behaviour of a temporal pattern which is repeated in all months of every year, in the same sector. This indicates that the identification of potential fishing areas is related to the physical and biogeochemical conditions of the ocean, which must be in the appropriate ranges for the presence of fish. In the graph of Figure 2, an example of the fishing effort during the month of June of the years indicated above is shown, by making use of heat maps using the KDE technique.

The experiment of this research is carried out specifically for June 9th, 2022, thus effective fishing events during the month of June 2020 will be previously analyzed, identifying the latitude and longitude of each one. In Figure 3, fishing events occurred during the above-mentioned month are shown. Subsequently, the physical and biogeochemical conditions of the ocean that took place in each of the aforementioned sites are recorded in a database.

Figure 2
2018 – 2020 Fishing Effort (Month June)
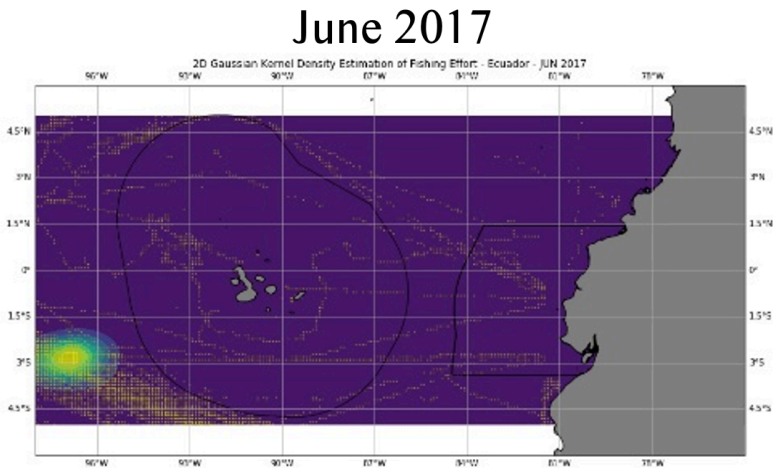
June 2018

June 2019

June 2020
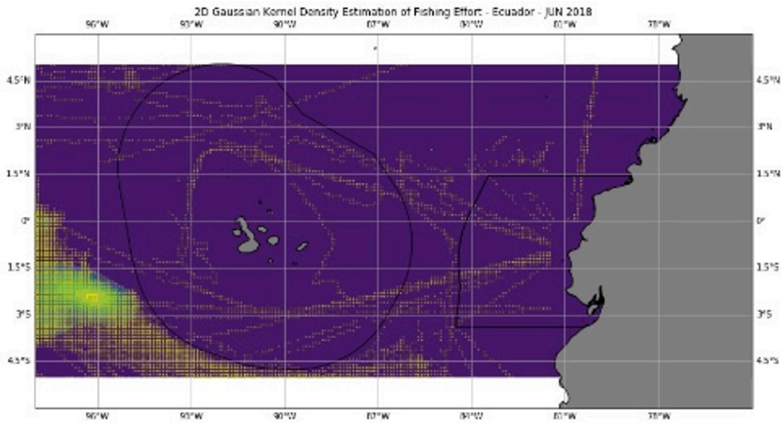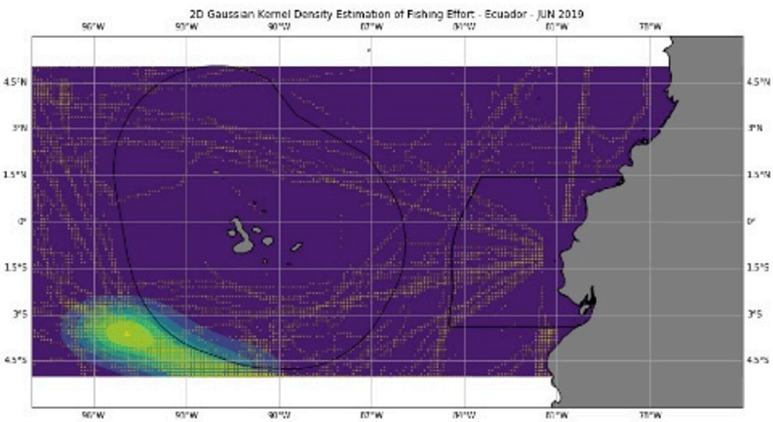
2D Gaussian Kernel Density Estimation of Fishing Effort - Ecuador - JUN 2020
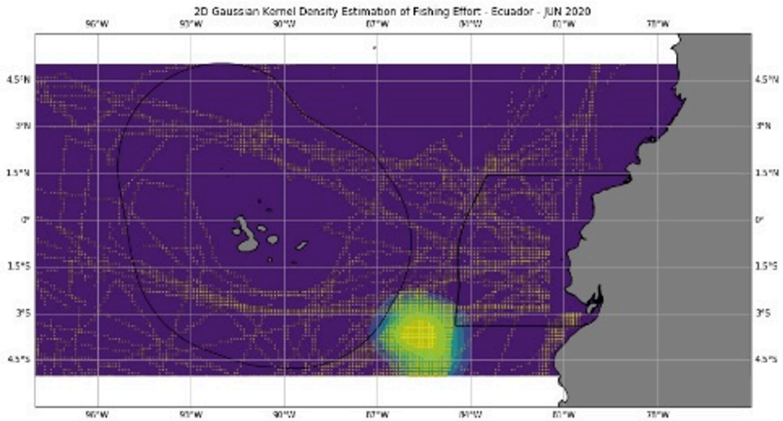
Figure 3
Fishing events occurred during June – 2020

2D Gaussian Kernel Density Estimation of Effective Fishing - Ecuador - JUN 2020
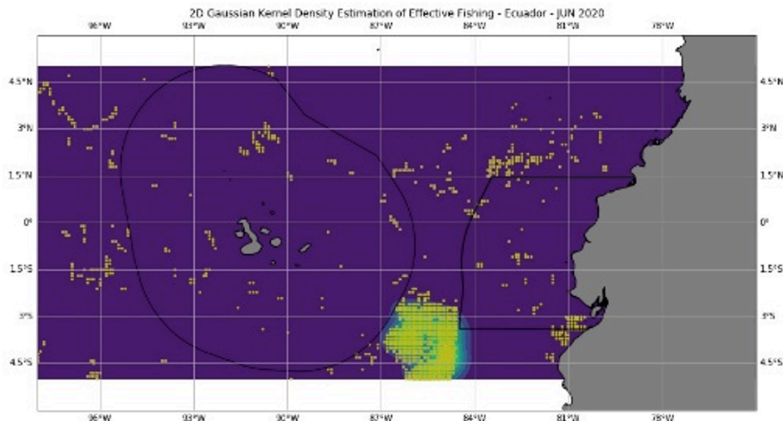
This data is processed using Python and by making use of a probability density analysis tool, such as histograms, it is possible to identify the range of every oceanographic variable where there has been a greater number of fishing events considering also the restriction that chlorophyll must be in a range greater than 0.5 mg/m3. Figure 4 shows the process of extracting data from the database of the physical and biogeochemical variables of the ocean, which are related to the fishing events of the month under analysis.

Since the day under analysis corresponds to the month of June, the range of each physical and biogeochemical variable was determined during that month in the year 2020, in the places where there was greater fishing activity and where the chlorophyll was greater than 0.5 mg/m3. Results are shown in Table 3.

Once the range of values of each oceanographic variable has been determined, the physical and biogeochemical conditions of the ocean in the study area on the analyzed day (June 9, 2022) are downloaded from the Copernicus dataset, and by making use of a software developed also in Python, a match of values for each of the ranges established for the variables considered in this study is searched.

Figure 4
Relation between Fishing Effort and Oceanographic Conditions
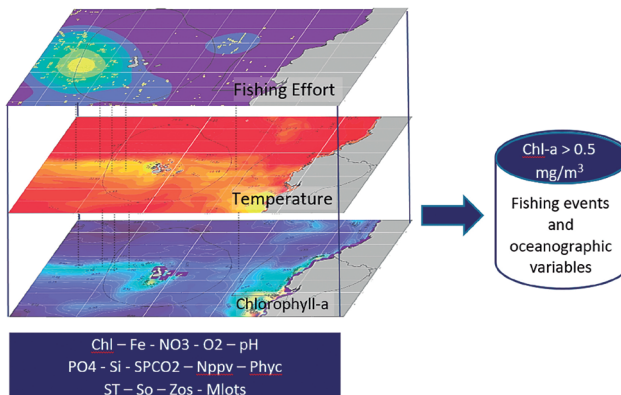
Table 3
Range of values of greater fishing activity – June 2020

PHYSICAL VARIABLES

	low	high
ST (°C)	19.89	21.80
So (1/e3)	34.93	35.29
Zos (m)	0.14	0.16
Mlotst (m)	10.53	13.17

NUTRIENTS

	low	high
Fe (mmol/m3)	7.99E-05	4.22E-04
NO3 (mmol/m3)	10.13	13.97
PO4 (mmol/m3)	1.07	1.33
Si (mmol/m3)	4.50	7.48

BIOLOGICAL VARIABLES

	low	high
chl (mg/m3)	0.50	0.98
phyc (mmol/m3)	3.09	4.35
nppv (mmol/m3)	14.73	27.71

CHEMICAL

	low	high
O2 (mmol/m3)	117.20	141.38
SPCO2 (Pa)	38.63	43.00
Ph	7.83	7.87

In order to increase the certainty in the prediction and ease the analysis, the variables are grouped depending on the type, that is, physical, chemical, biological and nutrient variables. In the geographical location where there is a greater match with the values established for the range of each variable, it is considered that this location meets the oceanographic conditions for repeated fishing events.

Finally, in order to identify a possible cluster or hot spot where a fishing event can be repeated, the kernel density function is used, and thus the area where the Navy should intensify patrolling to contribute to the protection of the marine ecosystem is determined. It is worth mentioning that the graphs which are used to determine the match of the values are also useful for planning the routes that must be followed to further increase the detection of vessels engaged in illegal, unreported and unregulated fishing.

Discussion of results

With the methodology used, a tool has been developed that helps us to understand the physical and biogeochemical conditions that fishermen seek to carry out fishing tasks. Once the ranges in which each of the variables are known, it would be possible to search for similar conditions that are repeated on the chosen day.

The analysis is carried out by type of variables, that is, by physical, biological, chemical and nutrient variables. Algorithms developed in Python are applied in order to search on the selected day and determine if those conditions are repeated. Two types of graphs are obtained: the first one, corresponding to the graphic representation of the match of the ranges of values in the sea and the second one, which is linked to the hot spot that identifies each group of variables.

The analysis is performed for June 9, 2022, and for physical variables, it has been possible to identify that in the northern region of the Galapagos Islands and Continental Ecuador, no conditions that are mainly related to temperature, salinity, sea surface height and mixed

layer depth have been presented, so the analysis must be carried out in the south-west area of Galapagos, as well as in the area between the continental economic exclusive zone and insular. In Figure No.5, the main areas where similar conditions existed as in 2020 are shown.

Likewise, this figure helps the Navy to determine the routes to follow in order to reach the hot spot, to further increase the probability of detecting illegal vessels. This approach must be carried out through a route that crosses the areas with the highest intensity on the map and taking into account the range of their radars.

The hot spot was identified using the kernel distribution density technique, the same technique applied to the data analysed in order to determine the maps which identify the areas where similar fishing conditions exist. In this case, the area that should be given the most attention is within the exclusive economic zone, to the south-west of the Galapagos Islands. Likewise, outside the EEZ, favourable conditions were also presented, which could attract the international fishing fleet. Figure 6 shows graphically what was described above.

Figure 5
Prediction of Fishing Areas – Type: Physical variables - June 9th, 2022
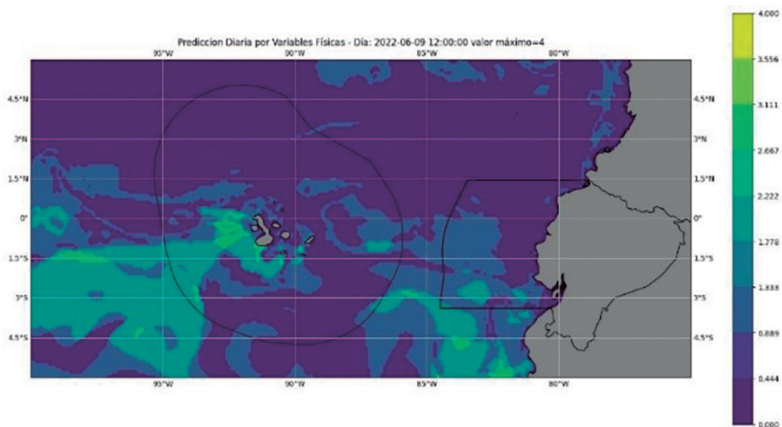
Figure 6
Fishing hot spot – Type: Physical variables - June 9th, 2022
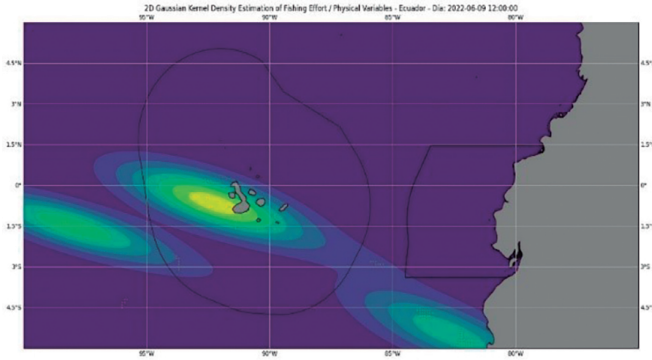
A similar analysis is carried out for the other groups of variables, in the case of biological variables (Chl, Phyc and Nppv). In Figure No. 7, it can be observed that there are also favourable conditions in the south-west of the Galapagos Islands and in the south-west of Continental Ecuador. It is worth mentioning that the favourable conditions also extend to the north of Perú.

Figure 7
Prediction of Fishing Areas – Type: Biological variables - June 9th, 2022
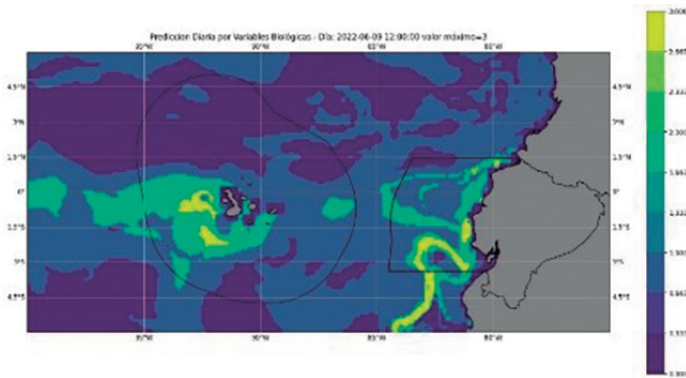
Figure 8
Fishing hot spot – Type: Biological variables - June 9th, 2022
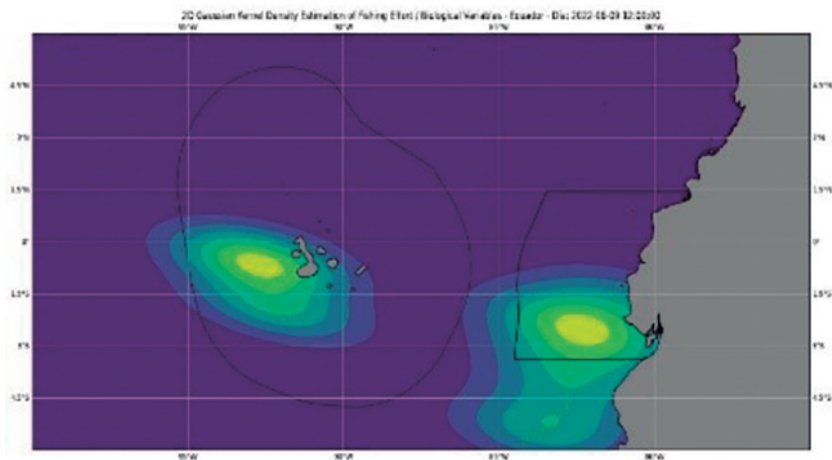
The representation of the hot spot of fishing location considering the biological variables in the insular region, is very close to the location determined with the analysis of the physical variables; however, there would also be another potential area inside the continental EEZ. Figure No. 8 shows what was detailed above.

From the analysis of the chemical parameters, it is evident in Figure No. 9 that, in the northern area of Continental and Insular Ecuador, there are no conditions similar to those occurred in June 2020, while in the south-west sector, both inside and outside the exclusive economic zone, as well as between both exclusive zones, appropriate chemical conditions would also exist.

When the hot spot is established, in reference to the chemical variables, it is again identified in Figure No. 10 that similar conditions are found in the south west of the Galapagos Islands; however, it can also be observed that between the exclusive territorial and insular zones, there is a hot spot with less intensity linked to this type of variable.

Figure 9
Prediction of Fishing Areas – Type: Chemical variables - June 9th, 2022
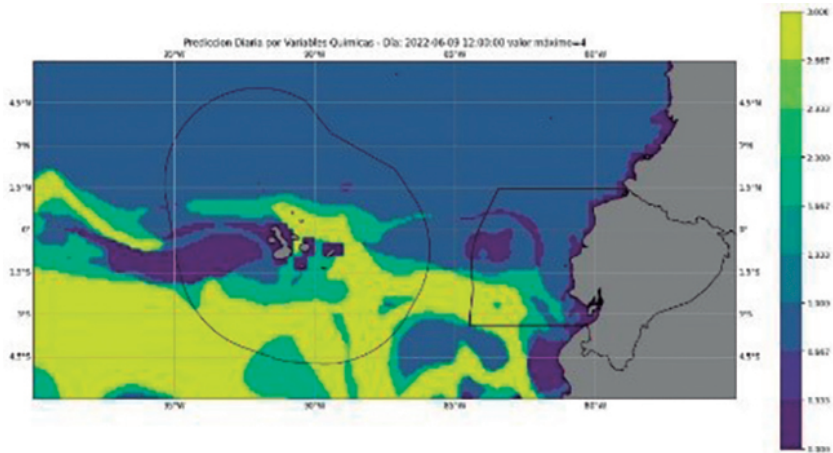
Figure 10
Fishing hot spot – Type: Chemical variables - June 9th, 2022
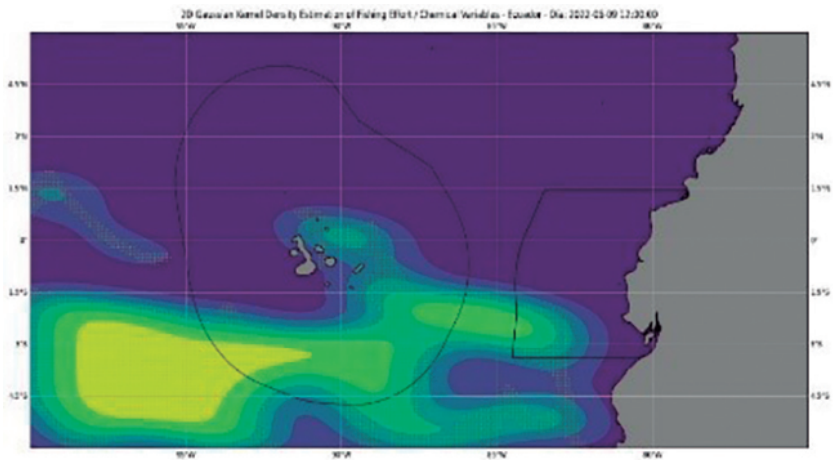
Respect to the analysis of nutrients, it can be indicated that they are found in a more concentrated manner in the middle of the continental and insular economic zones, which corresponds to the high seas, and in the north of Peru. Figure 11 shows the above and other areas that are important but less intense, which are located to the west of the Galapagos Islands.

In the case of the nutrient analysis, the hot spot varies its position with respect to what was identified when the physical and biological variables were analyzed; however, it has a certain relationship with the analysis carried out with the chemical variables, since there is a concentration in the middle of the exclusive economic zones. Figure 12 shows the above analysis.

Figure 11
Prediction of Fishing Areas – Type: Nutrient variables - June 9th, 2022
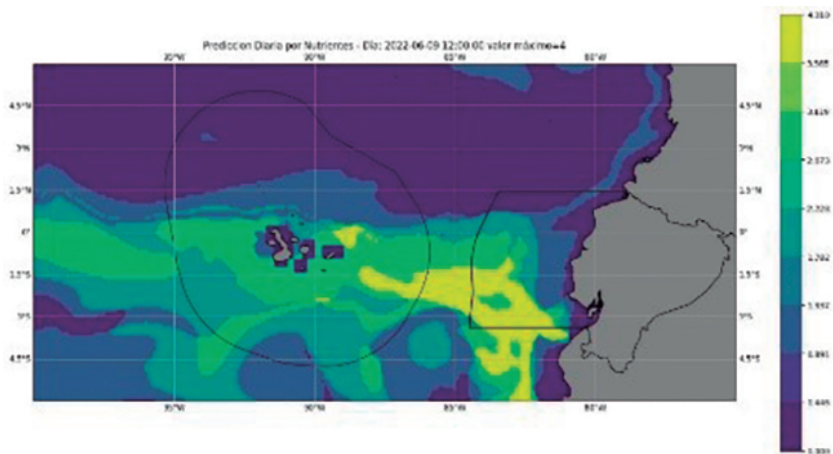
Figure 12
Fishing hot spot – Type: Nutrient variables - June 9th, 2022
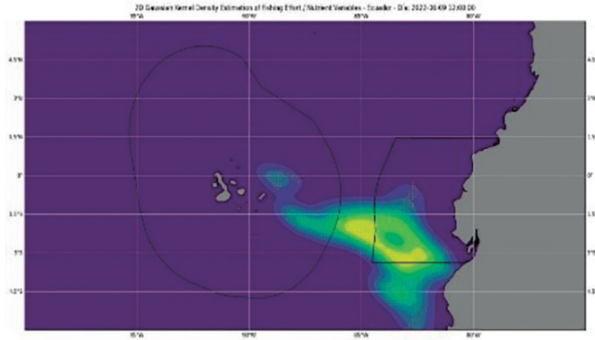
Finally, figure No. 13 consolidates the results obtained with the partial analyses of the physical, chemical, biological and nutrient variables. Meanwhile figure No. 14 shows the areas that present better conditions for fishing considering partial results of the variables mentioned before. For these reasons, these areas mainly should be fully guarded by the Coast Guard.

Figure 13
Prediction of Fishing Areas – Type: All oceanographic variables - June 9th, 2022
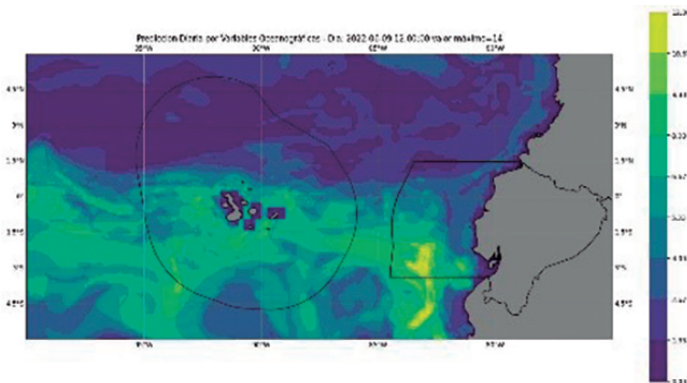
Figure 14
Fishing hot spot – Type: All oceanographic variables - June 9th, 2022
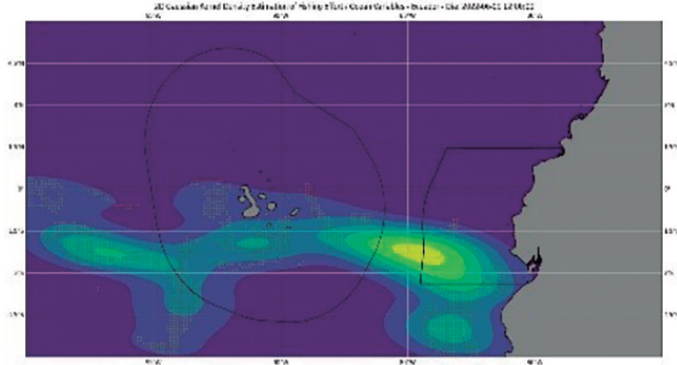
In figure 15, taken from the Global Fishing Watch platform, shows the real fishing effort in the study area on June 9, 2022, showing that there was indeed a presence of vessels in the southwest of the Galapagos Islands, as determined by the analysis of physical, chemical and biological variables. Similarly, there was a presence of fishing vessels in the exclusive economic zones, insular and continental, which also coincides with the analysis of physical, chemical, biological and nutrient variables.

Figure 15
Fishing activity on June 9th, 2022 – Source: Global Fishing Watch
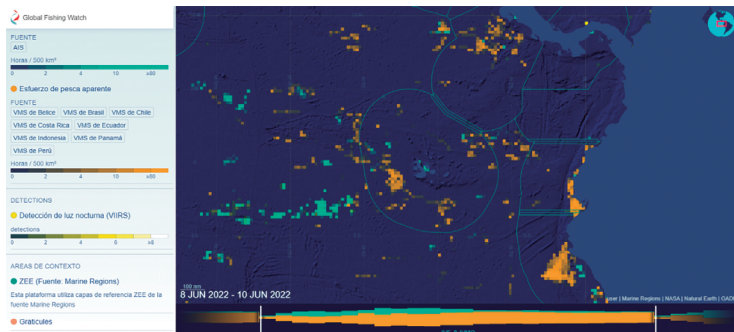
Conclusions

In this work, a daily prediction model of potential fishing zones in the continental and insular economic zone of Ecuador has been designed to provide the naval force with a tool to identify the areas that must be guarded in order to combat illegal, unreported and unregulated fishing. A methodology is proposed to determine the range in which the physical and biogeochemical variables of the ocean should be for optimize the fish presence, taking into consideration past fishing events and oceanographic conditions, which must be identified on the day the prediction has to be made. This methodology also helps to determine the routes to be taken by coast guard and aero-maritime exploration aircraft to approach potential fishing areas, to further increase the probability of detecting illegal vessels. Using statistical tools such as kernel density estimation probability, maps are produced to help determine the hot spots where surveillance and control efforts should be focused.

As future work, it is required to examine the behaviour of the fishing fleet in other years, in order to determine a range of values of the oceanic variables that allow generalizing the daily prediction of the potential fishing zones.

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Interactions in the Digital Learning Ecosystem in Teacher Learning Outcomes

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Abstract

Learning environments and interactions in educational contexts generate trans-formations in student learning, conceptual, methodological, and investigative trends are clearly identified; of those who assume the learning environments and their mediations, conceptions, origins, characteristics that emphasize those who learn, the knowledge and the educational community. Based on this research work, an application with augmented reality on autopsies is proposed, used by health science professionals, medical students from the health sciences faculty of Cauca, Colombia (semester 11). This research raises the need to describe and evaluate the learning processes in students and teachers who participate in the virtual modality from the "mediated didactic dialogue". In the country there is no systematic research on the experiences of students and teachers in the field of knowledge in the area of health mediated by interactivity in mobile applications Apps, which makes the study of the subject more demanding. The type of study of the present investigation is an observational study of analytical trend of longitudinal cut with prospective follow-up. Based on the need and opportunity expressed above, the following research questions are raised around which the development of this work is oriented; What impact does the use of mHealth Apps have on improving interactions and learning of legal medicine in medical students in train-ing? This look proposes a space methodologically constituted by two experimental design groups and they were correlated with the conceptual design of an interactive digital learning ecosystem mediated by necropath app, in this way the learning environments as an object of study proposes a domain articulation space as a theoretical and practical perspective that addresses the complexity of educational technological phenomena; operationalized in different phases: planning, learning outcome mediated by (VLE virtual learning environ-

ment - didactic sequence) and reflection on the teaching pedagogical praxis. At the same time, digital technologies are in processes of expansion and generalization in education. systems, allowing communication between students and teachers, so it is necessary to think of new pedagogical practices that promote knowledge processes, dynamic practices thought from the encounter in otherness and interactions with multi-situated thinking or group cognition, for bidirectional relationships between systems, virtual and human educational environments.

Keywords

Learning environments, learning interactions, digital learning ecosystem, significant experiences, legal medicine app.

Introduction

Information and communication technologies (ICT), increasingly pose new challenges and possibilities in the educational field. However, the focus cannot be solely on the use of these technologies since teachers with new skills and a continuous training process are needed in the knowledge society. Disruptive trends in technologies (1) reveal cognitive configurations that, in some cases, focus on "learning", privileging interactivity, under the assumption that in this way meaning is conferred on experiences and applicability of content. learned to real life situations. Another interest focuses on socialized learning, observing an experiential introspective trend, which aims to strengthen interactive structures in relation to the community and the cultural, this is seen as a way of manifesting comprehensive training from mediations pedagogical In addition, it is necessary to consider the implications that these mediations have for specific didactics, since today, teaching and learning communicable knowledge in the context of higher education is not the same as in the last century. This contrasted with today had these tools in terms of production of multiple mental representations of knowledge objects. Therefore, ists study, understanding and analysis leads to research in educational contexts. Following the reflections of Erazo (2), the concept of "technological mediation" supposes such a complexity that it intervenes in the multiple processes of cultural transformation that we are witnessing, in the midst of which the teaching and student subjectivities of the last decades are constituted. To speak of

mediation is to go beyond the simplistic position that assumes that the media-recipient relationship is one of cause and effect. Authors such as Martín-Barbero (3) and Serrano (4), introduced the term in our context and placed the media-audience relationship in a network of interactions.

Cognitive ecologies do not consider technology as an independent factor of people, but rather understand it as a dimension that produces meaning. Seen from this perspective, technology is understood as a human dimension. Beyond the devices, the technological universe configures societies, understood as individual and social *collective devices of subjectivation* (5). Technological ecosystems or cognitive ecologies are the aforementioned societal configurations. Understanding the phenomenon of technological mediations in education implies the recognition of an emerging system that arises from the tension between the instrumental paradigm (media and pedagogy) centered on educational institutions, with the ecosystemic paradigm, open and tending to techno-scientific development. cultural transformation, an issue that occurs outside the school context, whose dynamics come from *digital media*.

The Latin American and Colombian educational systems have favored teaching-learning processes, based on a dictator, rote and restraining dynamic, aimed at maintaining social structures of inequality and inequity. Education in medicine mediated by app with augmented reality has been careful to follow these pedagogical patterns with greater strength and inflexibility. Teaching in legal medicine has been influenced by positivist and biologist currents typical of the hegemonic medical model and its concept of primary care (6). Logic that has been difficult to overcome in the vast majority of universities in the country. In this framework, a clear interest emerges to understand virtual education, specifically dialogic interactions or dialogic model in interactions that studies them in the particular context of Latin America, Colombia, the department of Cauca, specifically in the case of medical students (7). The use of ICT applied to mHealth is a subject on which there are few studies. Regarding the evidence in relation to the benefits, there are dif-

ferent opinions and there is little information on the use and acceptance of ICT in mHealth in Colombia by users (9).

Based on the need and opportunity expressed above, the following research questions are raised around which the development of this research is oriented. ¿What impact does the use of necropath Apps have on improving social interactions and learning of legal medicine in medical students in training? Specific question What kind of interactions occur between the student-teachers and the necropath application? How to design and create a necropath application that contributes to collaborative learning on the subject of legal medicine? ¿ What kind of interactions occur between the student-teachers and the necropath application? And ¿How to design a DB APP model of learning ecosystems mediated by a necropath application, in the field of legal medicine?

Consequently, this research raises the need to describe and evaluate the learning processes in students and teachers who participate in the m-Learning model from the "mediated didactic dialogue". There is no systematic research in the country on the experiences of students and teachers in the field of knowledge in the area of health (legal medicine; mediated by interactivity in mobile applications Apps, which makes the study of the subject more demanding. In the present investigation the following general objective is proposed; To understand the impact that the use of a necropath Apps brings in the improvement of social interactions and the learning of legal medicine in medical students in training.

State of the art

Information and communication technologies (ICT), increasingly pose new challenges and possibilities in the educational field. However, the focus cannot be solely on the use of these technologies since teachers with new skills and a continuous training process are needed in the knowledge society. Disruptive trends in technologies (6) reveal cognitive configurations that, in some cases, focus on "learning", priv-

ileging interactivity, under the assumption that in this way meaning is conferred on experiences and applicability of content. learned to real life situations. Another interest focuses on socialized learning, observing an experiential introspective trend, which aims to strengthen interactive structures in relation to the community and the cultural, this is seen as a way of manifesting comprehensive training from mediations pedagogical In addition, it is necessary to consider the implications that these mediations have for specific didactics, since today, teaching and learning communicable knowledge in the context of higher education is not the same as in the last century. This contrasted with today had these tools in terms of production of multiple mental representations of knowledge objects. Therefore, its study, understanding and analysis leads to research in educational contexts.

Collaborative learning of the teacher in the app-mediated learning ecosystem (augmented reality): key in the online educational ecosystem

Personal Learning Environments (PLE), starting in the 21st century, began to develop and implement new technologies; defined by Castell "Knowledge Society" (SC), directed by the automation and easy access to Collaborative Learning courses (AC), determining that the organizations that make up the PLE, are in its entirety characteristics and processes of access to the information such as: search ports, digital skills of teachers (Ministry of Sciences, 2020 plan); with other app application plans (augmented reality), from the integration of existing updated personal learning environments, for which it is desired to make the implementation of this system more effective in innovative processes, directed towards the creation and innovation in terms of functional products for the information society (7), in which the criteria for the diagnosis of educational practice (EP) are identified, mediated by technological devices, from which the following learning models emerge: PLE and PLN [8].

Intersubjectivity and mediation:

Intersubjectivity occurs when there is a core of shared meanings. With this condition, it is possible to initiate a dialogical and negotiation process of meanings in the search for coincidences [9]. Here the intervention of the teacher becomes important to sustain the states of Intersubjectivation with their students and to broaden the base of coincidences about study [10]. In this process, both the student and the teacher interactively modify their perspectives; the teacher tries to appropriate the meanings of the student and the student seeks to signify the contributions of his teacher. As a negotiation of meanings progresses, different levels of intersubjectivity are produced, in which the teacher better interprets the meanings of the student, and the student perfects the conceptual meanings of its cognitive structure [11]

Computational Thinking (CT) from a socio-constructivist perspective.

The concept of Computational Thinking (CT), a high-level skill, related to a specific conceptualization model of human beings, develops ideas and links with abstract-mathematical and pragmatic thinking. The PC is not synonymous with the ability to program a computer, it requires thinking at levels of abstraction and is independent of devices. It has the characteristic of combining abstraction and pragmatism, it is based on mathematics, a world of ideas, and it is developed through engineering projects that interact with the real world; computational concepts, communicate with other people and manage aspects of our daily lives (12).

Computational thinking and augmented reality

Computational thinking seeks to solve problems by fulfilling a certain sequence of steps in the process through a methodology that uses technological elements; In this sense, some characteristics of computa-

tional thinking that support its greater adoption in learning strategies are a. formulating problems allows the use and knowledge of RIC as an aid in the proposed solution, b. Organize information sequentially for understanding, c. Obtain a structure of information through models and simulations. d. ddvance solutions through the structure of Algorithmic Thinking (AP), e. Identify, analyze, and implement solutions to achieve an effective and efficient mix of steps and resources.f. systematize and translate the structure of problem solving. g. when using the PC, it is evident that the skills to obtain maximum performance in the sense of skills are necessary in the computational world, with specific features (for example, with data and results gateways), but equally for the rest of activities that lead to some type of learning or development, the analysis has at least three dimensions, where each one is constituted without being exclusive or separated from the rest, a domain of study and research such as 1. Dimension of the situation of collaboration (group size, time period, affordances, communication, technological devices), 2. Type of Strategies and 3. Characteristics of "learning" and forms of collaboration (13) (14).

The challenges of education in the 21st century, "contemporary education" arises, must be approached from a holistic perspective in the current learning society, since social and cultural changes demand us to change the worldview of education in the century. XVI. The academic community then speaks of a comprehensive educational action to encompass the totality of being, apply the concept of holism in the teaching-learning process, in the role of the student, the role of the teacher and the contents of the personal learning environment Finally, the importance of the commitment that we must acquire as educators to respond to the demands that our society demands in relation to education is highlighted.

The role of the teacher in learning analytics

In the trend of learning analytics or also called "Intelligent learning" mediated by "mobile learning" it is widely used in student media

(whether university or college), as well as marketing and business, because it is a platform agile, seen from a technological point of view, because it allows easy access to information, carrying out a strict staggering of the things that are to be provided to the user, as well as access to information sought by static means such as a database ; therefore, all information related to ubiquitous media is more effective due to access and also "interaction with the medium and search", related to platforms that are commonly used from Web 2.0 to Web 4.0; (16) which integrate the information contained, in platforms that are connected through a network, allowing interaction with the external environment, which are located in classrooms or places where the software is available, showing that these platforms are robust.

Methodology

The methodological design of this research is oriented towards training in learning outcomes in eleven-semester medical school students in an educational institution through the development of the APP technological resource with augmented reality in practice scenarios; based on technological mediations in relation to mobile applications focused on M-Learning, which is associated with a learning theory conceived from five dimensions: individual productivity, interaction with other individuals, objects of study, educational work and cultural heritage, scientific method and technological, which allow pedagogical transformation by promoting the development of a learning route within the course, guided by ICT (17), in this way the inclusion of mobile technology in different models has generated the development of technological applications in education with a socio-technical perspective, which shows the interactions between "mobile technologies and the educational field", and how they are revolutionizing the new educational processes, in the field of mediations applied to Education.

Research design

In the present investigation, the study methodology based on "interactions in learning ecosystems", carried out in the year 2020 - 2022, in higher education institutions (IES); The research aimed to analyze the implementation of learning environments from the conceptual and methodological component, while contributing to the process of curricular integration and technological innovation. In this way, the importance of addressing aspects related to the characteristics of the learning ecosystem, activities, student-teacher-patient-colleague interactions, and practice scenarios is recognized. The design (DBR) was implemented that helps to understand the complex nature of real-life design learning problems [16], [17]. This methodology is frequently used to improve learning and teaching in mobile applications about legal medicine in medical students; Characterized by iterative cycles of theory-based reflection, analysis, and refinement, DBR aims to create individual tools or services and their respective learning practices to address specific challenges in learning outcomes.

The development of the research involved working with an experimental group, with a number of medical students twenty-three (23) of semester eleven, in which the participation of men and women was presented, in addition, it is important to highlight that the group had students from different parts of the department as well as from very similar socioeconomic strata among the participants.

Taking into account the characteristics of the investigation, a logical sequence was carried out that allowed the components to be developed in relation to a. Qualitative techniques, b. quantitative techniques, c. Analysis and decision making as referred to in Figure 1, Logical sequence for the research design Figure 1. (Own source).

Figure 1
Research phases
Own source

| Focus group sample 22 Students Poll App RA | Character technique quantitative | -Descriptive -Inferential | correlation |
| Qualitative technique | RA Survey. (learning result) Usability test Pedagogy | analysis | Validate the hypothesis |
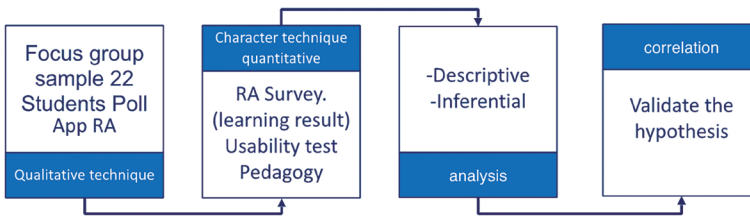
The objective of carrying out this research is oriented to compare the development in the learning results, through the application of the pre and post test, making use of a didactic strategy that led to the development of skills through the APP-reality mobile application augmented.

The legal medicine subject has a temporary duration of sixteen weeks (16), where the third week of class development was used to carry out the pre-test and from the fourth week the mobile tool was introduced, in the eleventh week it was carried out the evaluation of the post test and in the fourteenth week a usability test was carried out with the students that allowed knowing the inclusion of the use of Learning and Communication Technologies (TAC) in the classroom, within the subject. Additionally, a follow-up was carried out through the application of the work carried out by the students in the different spaces proposed through the processes of interaction and collaboration, the monitoring of the activities allowed the teacher to motivate the participation of the students, as well as to encourage those who do not participate, facilitating feedback processes in real time.

PHASES OF THE INVESTIGATION

In relation to the design, implementation and validation of the technological resource, the creation of a specific design was generated

in the subject of legal medicine through an app with augmented reality DTAPP with the intention of a teacher-student interaction configured in two levels of abstraction Figure 2. However, the process focuses on conceptual and technological integration in a learning ecosystem. A first version of a DBAPP conceptual design was configured, which is validated through experimental design through the presentation of three cases derived from a conceptual analysis.

Figure 2
Research design
Own source
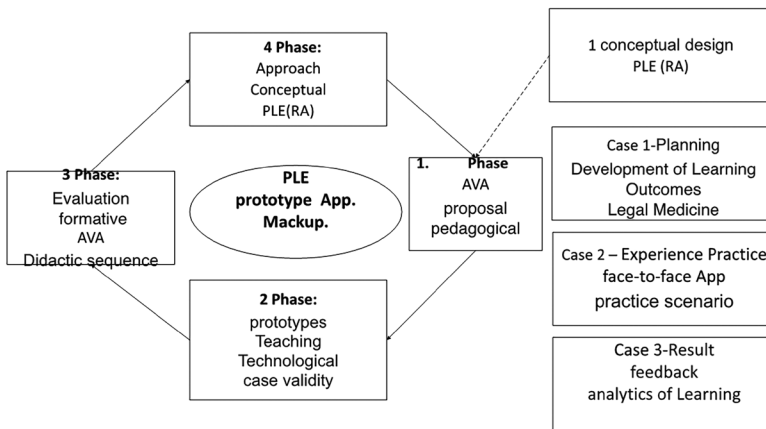
Phase 1: A problem in the learning outcomes (didactic sequence) is identified and analyzed in medical students prior to the experimental phase of the app in the subject of pathology (2020 years of registration), in the present investigation we propose a DBAPP framework with augmented reality that generated an approach to the formulation of practical needs based on scientific evidence, such variables as: learning outcomes, practice scenarios with augmented reality in the subject of legal medicine, design practices, when integrated into mockus prototype mockup (wire diagram).

Phase 2: Initially in 2020, the first app was registered with the virtual learning environment without augmented reality, which presents significant learning results when validating it. However, we continue the research line, we carry out our second experimental phase in the theme of app with augmented reality in the subject of legal medicine, for which a certification of teachers in digital content and content curation (institutional certification of the IES) and interinstitutional repositories.

Phase 3: Some pre-designs were made through the app's thread diagram, user manual, AVA (virtual learning environment), learning outcomes (faculty curriculum plan), new sketches of the prototypes with the teachers in charge (credentials of doctors in educational sciences), experimentation with external peers and attached to the faculty in relation to design, implementation and validation of prototypes.

Phase 4: An approximation to the DBAPP conceptual design of the teacher was made, in the last phase of the investigation a prototype of the DBAPP made in the experimental phase derived from the teacher-student interaction making the proposal is made.

Design experiment (Cases)

During the experimental phase, the technological prototype was designed and validated in relation to interdisciplinary work and validated by external peers with the aim of collecting information on the DBAPP design. The purpose of the experimental phase was to test the DBAPP components, in order to improve the design, examine their appropriation in practice scenarios in relation to interactions, which involved a higher education institution. The main objective is to analyze the teaching interaction when interacting technologies and how this knowledge is integrated into the DBAPP design.

Figure 3
Design of the digital learning ecosystem
Own source
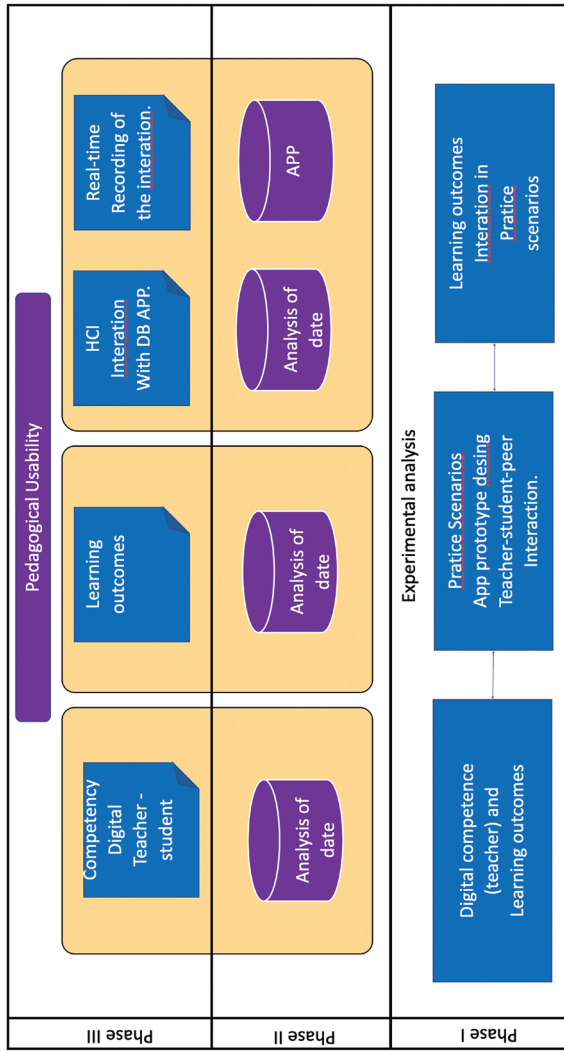
Case 1: Assessment of digital competence, Mockup

Learning outcomes
Case 1: Digital competence and learning outcome.
Objective: Criteria for evaluating ICT skills (Min Science) and learning outcomes: Teaching rubric.
Validation process in the DBAPP planning phase.
Sample: 23 students (SIGA)
Teachers: 3 teaching staff of the IES, the sample was taken in relation to the payroll of the institution, at the time it is a small sample.
Procedure:
Teachers received training in digital teaching skills within the framework of Min Sciences and in content curation in instructional design. Under the ADDI questionnaire, teachers reflect their experiences in a questionnaire.
En el presente estudio se analizó los niveles de competencias digitales y experiencia en ecosistemas digitales de aprendizaje.
Prototype: Self-assessment tool for assessing competence.
Evaluation: Análisis de contenido en las competencias digitales.

Case 2: Design, implementation, and validation of app application (augmented reality). Expert evaluation.

Sample: Teachers work collaboratively to build learning ecosystems. Experimental phase of software design and interdisciplinary work of instructional design, piloting and wireframes tests. 3 plant teachers participated, participated in the present study which participated in the pilot test, which had eligibility criteria.
Procedure: Enlistment: Phase I: Teacher training in instructional design and software, DRAPP conceptual approach, design, app application implementation.
Prototype: Development of thread diagram for app, conceptualization of DRAPP, entry to the platform and socialization in practical scenarios by teachers.
Evaluation: In the present study, the pedagogical usability test was carried out (results)
Includes interactions with DLR (collective – individual)

Case 3: pedagogical usability

Goal: Interaction of teachers in DB APP.

Sample: Three teachers attached to the program with academic credentials at the PhD training level: contribute to the design and implementation of DB APP.

Procedure: In 1 year, in collaborative work, the teachers created the DB and tested the designs (72) and tested in the different practice scenarios. Evaluation instrument is pedagogical usability.

Prototype: The evaluation tool is an online questionnaire for pedagogical usability and Monkey.

Evaluation: It was carried out with the google formats, monkey formats in the app and online format with the pedagogical usability criteria.

Figure 4
DesignDB APP necropat
Own source
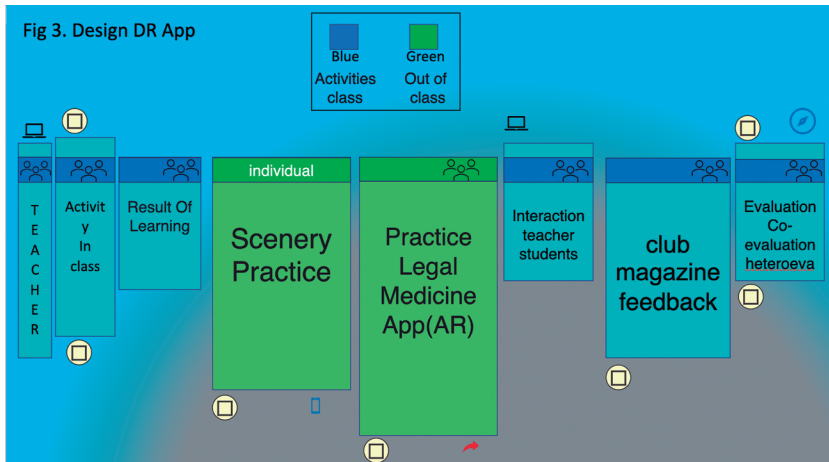
Consent to participate in the study

In line with internationally accepted standards to ensure the ethical treatment of people involved in scientific research, an informed con-

sent form was developed. The document will explain to the research participants in the focus groups the nature of the study, its objectives, as well as the right not to participate or to suspend their participation at any time and the confidentiality of the information provided to the participants.

Data Analysis Plan

The proposed methodology is complementary (quantitative and qualitative), the analysis of the data obtained according to their nature will be performed. For the processing and analysis of quantitative data, the statistical software SPSS version 4.0 for Windows, was used. First the descriptive statistics will be kept, including frequencies, calculation of measures of central tendency (mean, median and mode) and dissension (variance and standard deviation). The analysis is performed between differences of groups (T students test for independent samples and analysis of variance of a factor) and the degree of association or relationship between the variables (Pearson's correlation coefficient and chi-square tests).

The qualitative information collected will be analyzed with the MaxQda software, version 2018. The interviews are made recorded in audio format and subsequently transcribed and incorporated into the software for the organization and classification of data, summarize and tabulate them (data reduction). It will be done following the inductive method, based on the information obtained, the analysis categories will arise. Therefore, following the suggested methodology, qualitative data will pass to an analytical description to extract relevant information.

Results

This section presents the results that emerge from the experimental design in its three phases: learning results, design, and implementation of new practices in app development with augmented reality, ex-

perimental phase, practice scenarios. In the last section, we present the conceptual design of the DbAPP for teachers.

Evaluation of design experiments

Through the design, digital skills and learning outcomes were evaluated in teachers and students through necropath app mediation. 90% of the teachers perceived the evaluation as necessary in the process improvement plans. 10% report that the self-assessment makes them reflect on their pedagogical practice.

Main outcomes

The three teachers who participated in this study determined that digital skills were necessary and that they design and implement a learning ecosystem through a nacropath app due to the prevailing need for practice scenarios in health sciences. Upon entering the digital ecosystem, we monitor the activities and practices in the subject of legal medicine offering the student feedback activities and interdisciplinary management. We consider constant planning and evaluation in the development of integrated learning outcomes in the three phases.

Design and enactment of practices

In case 1 and 2, h5p activities are carried out, they are trained and a conceptual approximation of the DBAPP design is carried out. The following practice scenarios are proposed:

Inverted classroom. Students collaboratively apply knowledge in legal medicine in the problem resolution.

Problem-based learning: Problem-based learning. Student work teams are created, with each team member has a clear role. Students define the clinical case of interdisciplinary study, indicating the expected

results and a timeline. To achieve the goal of the project, individuals continually engage in collaborative interactions with DBAPP.

Learning in practice scenarios: clinicopathological correlation

Task based learning. An example of a LD designed as a flipped classroom activity described in Figure 3 using the LePlanner web application.

Activities are carried out individually and collaboratively

Figure 5
App Interaction necropat
Own source
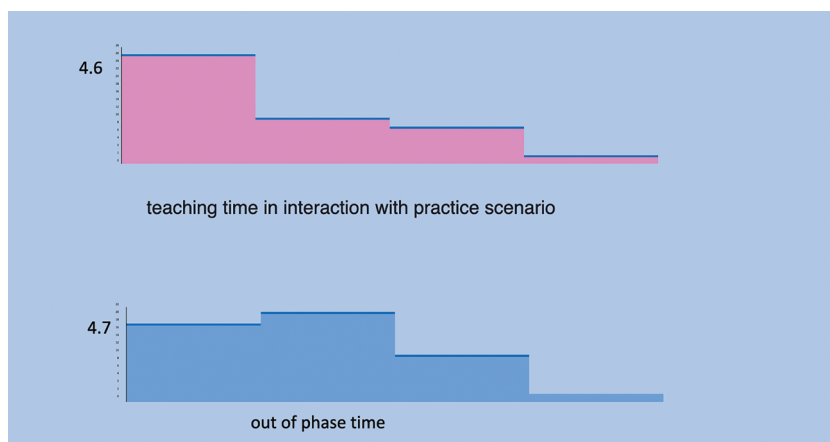
The teachers who participated in the present study (n=3) mentioned that the use of DB APP provides automatic feedback for the students based on their interactions,

Evaluate the digital ecosystem in class.

The teachers who participated in this study monitor the activities of the didactic sequence in real time with continuous feedback activities.

Fig 4. The analysis of the answers of the professors showed in relation to the constant feedback when implementing the design in the learning of the students happen as expected. Research has shown that teachers primarily struggle to choose pedagogical actions in response to data.

Conceptual design of a digital learning ecosystem

in this section, a conceptual design of DLE for teachers situated learning will be proposed. Design experiments carried out as studies to understand the pedagogical, technological, and methodological aspects integrated to the design of the integrated DRAPP have not been validated in design experiments.

Dimensions of the proposed DBAPP

The technological dimension of our DBA APP is an app application (necropat), mediated in the learning of teachers and students. These are online web applications (androi and IOS operating system), developed as part of the design experiments described in section IV reflected in each session with their permanent feedback. (See Figure 4).

Phase I: of the app system consists of web services used by teachers in the different phases of their interactive learning. Coast of web applications Tinada and LePlanner

Tinda is a web application based on Drupal. The conceptual approach that was generated in the present investigation, DBAPP, generates significant learning in real time for medical students in the subject of legal medicine

The design and implementation of DB APP, was done through a thread diagram, the interfaces include H5P, includes metadata and data mining to describe the DB based on learning outcomes, curricular themes. In the contents of the sessions with the respective themes, they

generate interactions and provide feedback in real time, generating a habitus in the students.

Phase II: The phase analyzes the information in databases and stores the records of learning outcomes in relation to each topic. Interactions are automatically annotated with a specific category (domain concept used in taxonomies and domain models), links students to learning outcomes.

Teachers base digital skills on their pedagogical praxis; by generating innovative proposals mediated by disruptive trends.

Discussion

The changes in the learning processes require educational experiences that allow to promote and take advantage of the communicative and creative capacity of the student body; in this case, mobile devices play a key role in the process (18). To contextualize, according to reports collected in Technological Perspectives: Higher Education in Ibero-America (19), mobile devices are considered as: "one of the emerging technologies that will have a significant impact on education" (20).

Didactic strategies are defined as the procedures (methods, techniques, activities) through which the teacher and students consciously organize actions to build and achieve planned and unforeseen goals in the teaching and learning process, adapting to the needs. of the participants significantly. In relation to social interaction, it was validated by applying pedagogical usability and a percentage of 76% was generated in heuristic 5 in relation to the interaction between peers - students, student teacher 56% and students - teachers - external peers 47%.; The correlation with the research (21) in relation to the data found in relation to usability, navigation and content design, mainly in social interaction between students and peers, was 79%, with significant differences using the app in teaching-learning processes.

The integrated DBAPP was validated in phase II and III in future research. Comprehensive validation requires a study that encompasses in a single intervention all the important phases, pedagogical, social, and pedagogical approaches. A large-scale and longer-term study of the digital learning ecosystem is needed.

Conclusions

Most of the evaluation proposals in university contexts of medical students in relation to learning outcomes correlating Computational thinking focused on the computing or programming skills that the students possessed.

This research provided evidence of reliability and validity (Conbrach's alpha) in its studies on the evaluation of computational thinking (CT).

The design and implementation of app with augmented reality as a didactic in teaching and learning inspiring them in computational thinking PC computational thinking of university students. Assessments are part of a broader project to bring computational thinking to practice scenarios in university educational contexts with an interdisciplinary collaborative group.

Currently Learning Analytics help us solve some problems in which we find ourselves immersed; for example, it is an excellent aid for diagnostic and formative evaluation in the adaptability of learning resources, to improve personalized planning within the PLE (personal learning environment), for real-time tutoring. Likewise, it can also help us to establish models associated with competencies and learning outcomes (in addition to validating their effectiveness).

From the results of the study on "interactions in the digital Learning ecosystem in teacher Learning outcomes", some conclusions grouped from the dimensions that were proposed in the study are presented, to give way to recommendations that are considered in the learning de-

sign of real life through DBR (design-based research) in collaborative environments.

This study showed that some topics of digital ecosystems and learning environments are more visible than others. Topics such as the recognition of the characteristics of the students, clinical management of the study of legal medicine combined with augmented reality, the approach of disciplinary knowledge, the establishment of conditions in meaningful learning in real time, the teacher-student relationship, communication , or evidence of pedagogical intent, are more frequent (greater than 70%); followed from the work from an interdisciplinary perspective, student-student interaction, student teacher, external peer students or evidence-based interdisciplinary clinical management (30%).

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Setting-up the Audiomoth Recorder for Wildlife Monitoring in the Rainforest

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Abstract

Ecoacoustics is a widely used wildlife passive monitoring discipline. Professional audio recorders offer robust casings able to resist adverse environmental conditions. However, the need of using clouds of recorders (for e.g. landscape level analyses) is obligating most researchers to migrate to low-cost devices, which unfortunately do not offer robust low-cost casings. In this work, we propose a home-made casing design and define a protocol of experiments for testing the recorder performance under real-life condi-

tions. Specifically, we set-up an Audiomoth recorder for long-term wildlife monitoring in a Colombian rainforest and as a result, we find that it behaves similar to a professional SM4 recorder in terms of gain and dynamic range, and better in terms of soundscape information provided.

Keywords

Audiomoth · Song Meter · Ecoacoustics · Casing.

Introduction

Passive-monitoring of biodiversity with audio recordings has become a standard technique to study wildlife [6, 16, 17]. It allows from characterizing specific species behavior [2, 20] to finding environmental acoustic indicators when monitoring extensive geographic areas [5, 11, 18]. Several brands provide professional audio recorders with robust casings that protect them from the environment (such as the SongMeter–www.wildlifeacoustics.com or the Bioacoustic Recorder –www.fron tier-labs.com.au) [3], as long-term monitoring requires fixing these devices for weeks/months in the wild. In our particular experience, we have used SongMeter recorders (SM2/4) for monitoring biodiversity in Colombia [2,5,7] and we have identified two main drawbacks: their price is prohibitive for large-scale studies of landscapes (approx. USD$1000 per device), and their microphones are not fully protected. About the latter issue, we have observed that insects (mainly fireants) eat their foam protector and the constant rain wets the microphones, rapidly (and permanently) degrading their gain (see Fig. 1).

The high-price problem has been tackled by several researchers who are developing low cost wildlife recorders [1,6,9,10,12,15,19], but the protection-to-elements issue remains because these devices do not include a proper case. Protecting audio recorders from the environment is not a widely studied issue because established companies offer excellent cases with their devices, and the use of low-cost recorders is still at its initial steps. Additionally, these devices are still mostly used under controlled conditions or short periods of time. But bad-casing in long-term wildlife monitoring could derive in loss of the device and its information.

Figure 1
Causes of deterioration of recorders exposed to real-life conditions

Due to the success of the Audiomoth open-source recorder (approx. USD70) designed by Oxford University researchers [8,9], its developers initially proposed a simple casing [9] and recently a robust waterproof one (IPX7 https://www.openacoust icdevices.info/case). However, its cost (close to the price of the recorder itself) is still too expensive for monitoring with hundreds of devices. Therefore, in this work we propose a set-up for the Audiomoth recorder (or any similar device) with a homemade low-cost alternative (less than USD$5 per case) that could be easily produced. We compare it (both in terms of audio quality and protection from the environment) with a SM4 recorder as a gold standard [13], and with two other commonly used options (a freezing bag and an aluminum paper bag). We test their:

i) audio quality under controlled conditions, ii) audio quality under real-life conditions (tested in a rainforest), and iii) long-term performance.

This paper is divided as follows. We start describing the proposed casing and experimental conditions for setting-up the device in the Materials and Methods section. Then, we present comparative results focusing on dynamic range and loss of gain; and we finish presenting our conclusions.

Materials and Methods

The set-up proposed here is intended for long-term (weeks/months) monitoring of wildlife either for species identification or acoustic-index analysis purposes. This set-up has two key components: building a low-cost casing able to keep the recorder dry and safe while guaranteeing good audio quality, and configuring the gain for an optimal recording

Recorders and casing

We use a SoundMeter SM4 recorder (Wildlife Acoustics, Inc.) as gold standard. This recorder is sold in a sealed robust waterproof casing (See Fig. 3), it features stereo programmable recording, a sampling frequency of up to FS=44.1 kHz, a linear response of up to 5 kHz, and quasi linear response of up to approx. 12 kHz (as reported in its datasheet). Additionally, we selected the Audiomoth recorder (Open Acoustics research) as the low-cost alternative. It is open-source, mono, with a built-in microphone and a FS of up to 192 kHz. According to the developer, it showed a SNR of approx. 5 dB less than the SM2 (same microphone than the SM4; www.openacousticde vices.info/audio).

The main issues for performing passive recording in a rainforest are the rain, humidity, and animals (especially insects). The proposed casing for the Audiomoth consists of an hermetic plastic box for food (available at any store) with the next modifications (see Fig. 2): 1) the size of the recorder and the box must be similar; 2) drill a hole of 10 mm in the microphone position; 3) cut a hydrophonic speaker grille cloth

and 4) glue it with acrylic waterproofing; 5) cut a foam to cover the recorder, 6) to fit the space within the box.

The Audiomoth developers suggest that a resealable freezing bag is enough for most outdoor recordings. Therefore, in preliminary tests we added some other possible casings for comparison purposes (freezing bag, aluminum paper bag, waterproof plastic bag for smartphone, and an hermetic plastic box for food without modifications). In all cases the built-in microphone was properly separated from the casings with dishwashing sponge and tape. We found that the sealed bag for smartphones and the plastic box significantly attenuated the gain, so we discarded them. The casing of the SM4 was not modified.

Experiments

We first tested the different casings under controlled conditions for having a loss of gain baseline and looking for reduced dynamic ranges. Then, we repeated this test under real-life conditions at a coastal-rainforest (Buenaventura, Choco region in Colom-´ bia). Finally, we performed a long-term test under real-life conditions in two different rainforests (Antioquia region, Colombia).

For all experiments, the SM4 was configured at its maximum frequency sample of FS=44.1 kHz. The audiomoth was configured at 48 kHz as they do not match on their available options. We used their own default gains (reported at 16 dB for the SM4, mid -unknown value- for the Audiomoth). For the initial experiments, we configured both devices for recording 1 min every 5 min in WAV format, with clock differences among devices of less than 2 s. For the long-term validation, we extended the recordings to 1 min every 19 min. In a preliminary test (not shown here), we tested three SM4 and ten Audiomoth devices, and verified that the gains within devices of each brand were similar between 20 Hz and 10 kHz.

Figure 2
Design of the proposed casing
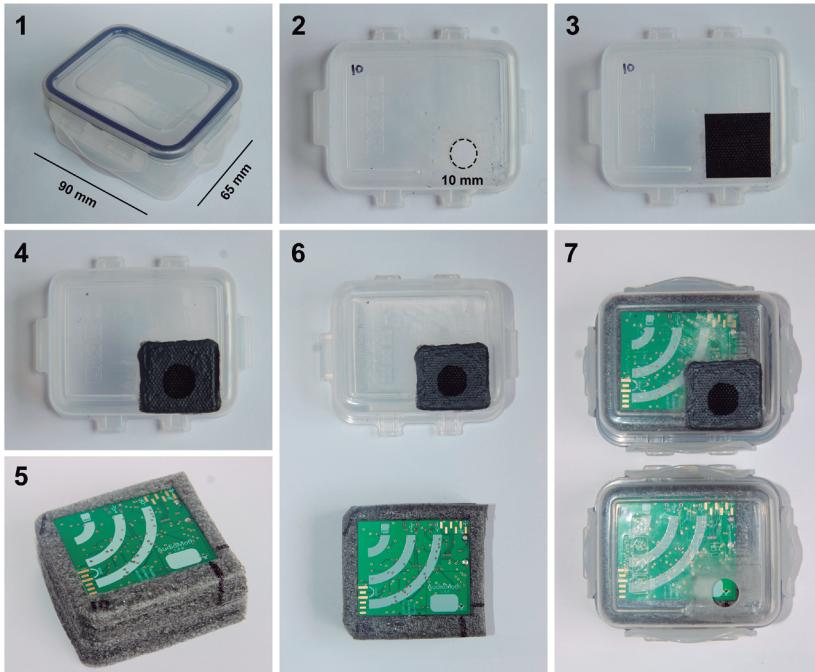
Controlled conditions We started placing the recorders with casings shown in Table 1 in a silent room and played twice 30 s of music. The music was previously selected for having similar power in all frequencies up to 12 kHz (see Fig. 4). We discarded the use of synthetic generated signals (such as a chirp) because they do not show the typical complexity of sounds of a rainforest, so a good result with them would not be representative of the real-life issue. Additionally, in previous tests (not shown here) we found that the gain of the chirp or sinusoids provided by different types of speakers were not stable.

The post-hoc analyses consisted of averaging power spectrum plots from recordings. Then, correlation among spectra and mean level differences were computed. The two (stereo) channels of the SM4 were averaged for comparison purposes.

Table 1
List of recordings and casings used for testing

Label	Recorder	Casing	FS	Gain
SM4	SM4	Default	48 kHz	Default (16 dB)
A1	Audiomoth	Without casing	48 kHz	(mid –Default)
A2	Audiomoth	Freezing bag	48 kHz	(mid –Default)
A3	Audiomoth	Aluminum bag	48 kHz	(mid –Default)
A4	Audiomoth	Proposed casing	48 kHz	(mid –Default)

Figure 3
Positioning of the recorders for the experiment

Real-life conditions The next step consisted of determining the dynamic range and gain of the configurations shown in Table 1 under real-life conditions. For this purpose, we tested the devices in a Colombian tropical rainforest located at approx. 45 km from Buenaventura port. Fig. 3 shows the actual placement of the devices. Post-hoc analyses are the same of the previous experiment.

Gain selection The last step consists of determining the true gain levels of the Audiomoth recorder. This device can be configured with five levels but the developers do not provide information about gain differences. Therefore, we placed six devices (Five Audiomoth + one SM4) for 12 hours in the same location (recording times: 6pm–8pm and 3:30am–6:30am), each Audiomoth with a different gain. Post-hoc analyses were the same of the two previous experiments.

Long-term recordings To validate the proper function of the proposed casing, we placed an SM4 and an Audiomoth with the proposed casing in two different rainforests: Anor´1, and Amalfi, in Antioquia region, one week each. With this, we expect to reduce the bias introduced by the acoustic landscape, as these are uncontrolled conditions and the recorders could show a different response in a different environment. The configurations of both recorders were the same ones of the first experiment, except for the duration of the recordings, which was 1 min acquired every 19 min, for a total of 3,532 recordings.

We used the Ecoacoustic Global Complexity Index (EGCI) [4] to compare the recordings. This index represents the state of an acoustic landscape, by taking into account the characteristics of the signal in both time and frequency domains. The EGCI index is based in the combination of three measures of information: Shannon entropy, Jensen-Shannon divergence, and generalized statistical complexity. It is represented in the HxC plane (entropy vs. complexity) and is used to study complex dynamic systems [14]. In this way, we characterized the recordings by including all the soundscape information.

We used the methodology described in [4] to calculate the EGCI index. Briefly, one computes the autocorrelation of each recording; then, a singular value decomposition is performed and a probability density function (PDF) of its histogram is obtained, from which the tree measures of information are computed. As a result, each recording provides a coordinate in the HxC plane. This index requires defining an initial parameter τ_{max} corresponding to the time lag. In our case, this parameter was fixed to $\tau_{max} = 256$, since this value allows speeding-up the calculations and delimiting points (recordings) in the minimum and maximum limits of generalized statistical complexity, as explained in [4].

Results

Controlled conditions

Figure 4
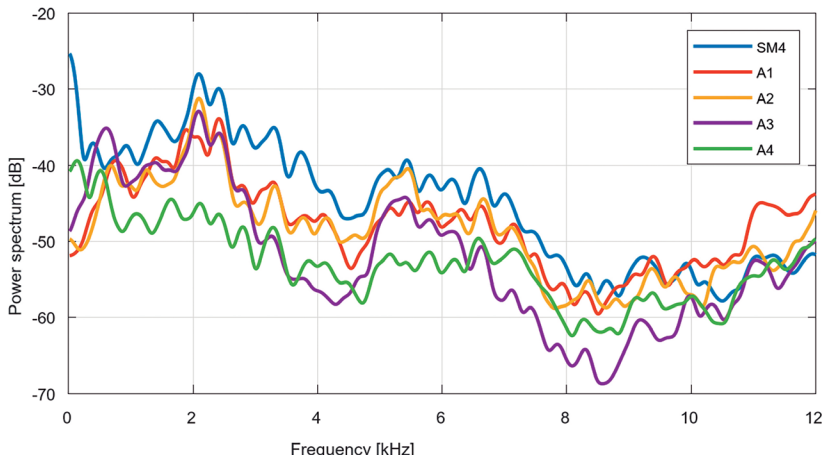**Power spectrum comparison under controlled conditions**

Fig. 4 shows the power spectrum (limited to 20 Hz–12 kHz) with the casings of Table 1. The mean loss of gain with respect to the SM4

was 2.72 dB for the Audiomoth (A1), 3.62 dB and 7.17 dB for the freezing and aluminum bags, A2 and A3 respectively; and 7.93 dB for the proposed casing (A4). This means that under controlled conditions the Audiomoth looses approx. 3 dB against the SM4 (for a 1 kHz pure sinusoid, the developers estimated approx. 5 dB). The freezing bag behaves close to no having protection, and the proposed casing looses 5 dB with respect to the Audiomoth itself. This figure also provides information in separated bands. We detected a high gain of the SM4 below 200 Hz. We consider this test valuable as music allows testing true dynamic range of devices and casings, because sometimes real-life performance significantly differs from datasheets.

Real-life experiment

Fig. 5 shows the same power spectrum but for real-life conditions (average of 5 recordings in a rainforest –1 min each). The figure shows the expected larger gain of the SM4 at very low frequencies, but it also shows a linear reduction of gain for this recorder after 9 kHz. Although expected (from the datasheet), this behavior was not evident under controlled conditions (the trend was confirmed in individual recordings). Similar to the previous experiment, all casings behaved similarly with the exception of the peak at 6.6 kHz, where the proposed casing showed lower gain. Finally, by analyzing individual recordings we found many noise stamps from the aluminum bag in A3 (presumably due to wind).

Under real-life conditions the average gain differences with respect to the SM4 were lower for all cases: The Audiomoth lost 0.99 dB (A1), the freezing bag 2.88 dB (A2), the aluminum paper bag 0.45 dB (A3), and the proposed case 3.4 dB (A4). We also checked for the average correlation among devices. Between the SM4 and the Audiomoth without protection (A1) it was 86.62±0.71 %, mostly downgraded by the low and high frequency disparities of the SM4 (between 300–9 kHz the correlation was 95.4±1.85 %). The others were computed against the Audiomoth (A1) for a fair comparison: *Corr*={A2 : 93.24±2.88 %,A3 : 91.64±5.84 %,A4 : 88.03±2.63 %}.

For the third experiment, we tested the five gain levels of the Audiomoth to determine the optimal one for our proposed casing. Fig. 6 shows the average power spectra of the 50 recordings obtained during two windows within 12 hours in the rainforest (some of them with heavy rain). The figure shows how the two lower and the two higher gain levels are close to each other. The loss of gain against the SM4 for each level (from low to high) are: $G=\{14.29\pm0.60, 12.74\pm0.57, 7.29\pm0.73, 2.13\pm0.52, -0.54\pm1.04\}$ dB. Note how the gain of the high level is even higher than the SM4; however, listening to the individual audios we observed that this result is tricky, because there were many saturation

Figure 5
Power spectrum comparison under real-life conditions.
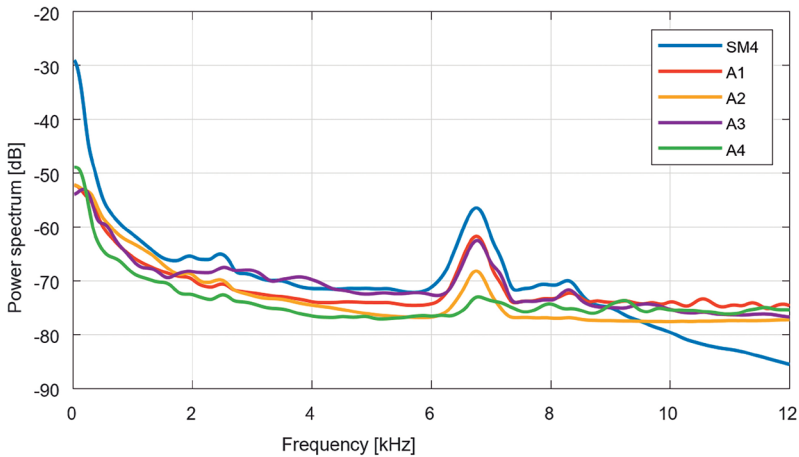
Figure 6
Gain comparison after 12 hours test.
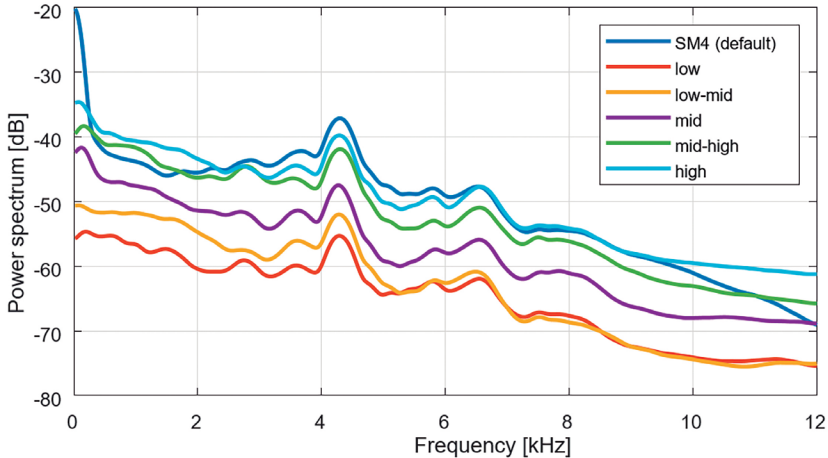
This experiments showed that our proposed casing, although behaving similar to other options, with default gain presented a slightly lower gain than just using a freezing bag (which behaves as if there was no casing). Therefore, why choosing it? because of the rainforest. Under long-term real-life conditions a robust casing is mandatory. As a toy example, we took both the proposed casing and some freezing bags (filled with cookies) for a field study at a rainforest. After just one week, all freezing bags had insect holes and were wet or even flooded (same problem sometimes observed with the SM4 microphone foam protector), while the proposed casing was not degraded. Moreover, the proposed casing has been used by our research team for more than two years without issues.

Long-term real-life test

Fig. 7 shows the projection of the recordings in the HxC plane for the two recorders in the long-term experiment. The difference between

the two clouds was quantified using the correlation of each point. We obtained a value of Corr={0.43,0.21} for the entropy and the complexity, respectively, which are shallow correlation values and show the differences that exist between both recorders. Additionally, the cloud of blue points corresponding to the Audiomoth recorder tends to be located in the lower right region (near the color noise line). Since the Audiomoth has a higher gain after 8 kHz (as shown in Fig. 5), the additional information obtained from these frequencies modifies the behavior of this device in the HxC plane and causes this displacement of the point cloud, which translates in more relevant information provided by this recorder.

Figure 7
Distribution of the acoustic samples (EGCI values) in the HxC plane.
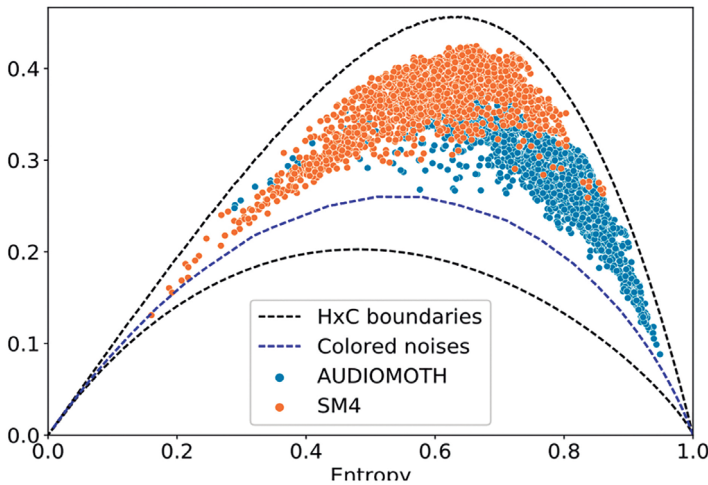
The abnormally higher low-frequency and lower high-frequency gains in the SM4 prevent a fair comparison among devices. Therefore, we applied a bandpass filter (order 615) between 500–8 kHz with a Hamming window of length 1024 to all recordings. Fig. 8 shows the resulting EGCI index with the filtered signals. For this scenario, the

clouds overlap far from the color noise limit, which means that in the HxC plane, the dynamic systems represented by the two recorders show a similar behavior. We calculated the correlation values for each of the data points after applying the filter. The correlation increased significantly to Corr={0.79,0.67}, evidencing that both recorders could resemble and be used in multisensor research as long as the appropriate preprocessing is performed.

Figure 8
Distribution of the filtered acoustic samples (EGCI values)
in the HxC plane.
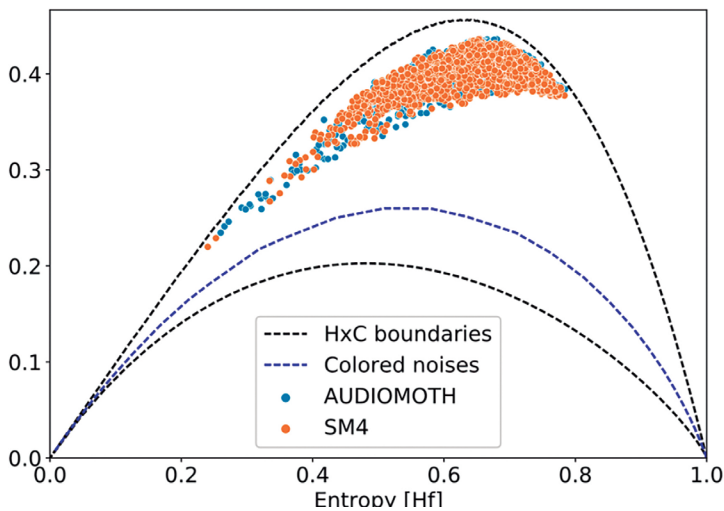
Conclusion

In this work, we proposed a protective casing for an Audiomoth wildlife recorder expected to be used in long-term monitoring under rainforest conditions. We used a professional SM4 recorder as gold standard. Controlled conditions analyses showed that the proposed casing

looses higher gain (with a default configuration) than other protectors (such as a freezing bag), but with similar overall performance. Real-life tests in a tropical rainforest showed similar performance. A long-term test demonstrated that the Audiomoth with the proposed casing even provides more soundscape information than the professional SM4 recorder, but that they can both be used together with a proper preprocessing. Finally, this proposed casing did not show degradation after long-term real-life field tests.

Acknowledgments

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HAND GAMES: Reforzar la Motricidad en Personas de la Tercera Edad

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Abstract

Technology provides benefits for the society from communication, information, recreation, health, etc. As a result, several tools have been developed and are used as supplements in certain fields, such as healthcare. In order to support treatments, especially for older adults, echnology contributes to the care of their physical and mental health, providing a sense of well-being. Additionally, they enable timely disease detection and the application of appropriate treatments. This project focuses on the use of hand tracking technology (recognition of hand points in a three-dimensional space) applied to physiotherapeutic treatment for older adults through video games, aiming to reinforce fine motor and psychomotor skills.

Keywords

Physiotherapy · three-dimensional space · motor movements · psychomotor.

Objetivos

Objetivo general

Realizar un videojuego con el uso de la tecnología hand tracking para el apoyo a los tratamientos fisioterapéuticos de personas de la tercera edad con el fin de estimular correctamente sus movimientos motrices y psicomotrices.

Objetivos específicos

- Realizar el levantamiento de información necesaria mediante encuestas a profesionales en el área de fisioterapia para adultos mayores enfocada al diseño de interfaces gráficas.
- Investigar las herramientas Python, OpenCV y Media Pipe para el desarrollo del movimiento del mouse por hand tracking.
- Investigar las herramientas C y Unity para el desarrollo del paquete de tres juegos de motricidad y psicomotricidad.
- Integrar el controlador por hand tracking al juego.
- Realizar las pruebas correspondientes con la participación de adultos mayores del centro terapéutico.

Introducción

En un rango entre los 60 años en adelante, las personas mayores tienden a perder diferentes habilidades, y entre ellas están la motricidad y psicomotricidad. En un adulto mayor, estos factores se manifiestan con lentitud principalmente en los reflejos, incluyendo la descoordinación de movimientos que producen accidentes domésticos, además de la pérdida de orientación, memoria y manipulación de varios objetos empleados en la vida cotidiana. los datos de... una de las maneras de poder evitar este tipo de inconvenientes es realizar ejercicios psicomotores y de motricidad fina para ayudar a reforzar estas habilidades, a través de programas didácticos, basado en este concepto se ha visto la necesidad de implementar el presente proyecto que consta de tres juegos manejados por la tecnología de hand tracking que buscan apoyar en los tratamientos fisioterapéuticos enfocado a la movilidad física de los adultos mayores..

Marco Teórico

Motricidad

Este término hace referencia a la capacidad del ser humano de poder controlar los movimientos de su cuerpo con la intervención de todos sus sistemas, siendo el motor aplicado a todo tipo de aprendizaje [1].

Tipos de motricidad

Motricidad gruesa: Este tipo de motricidad hace referencia a las acciones en las que intervienen la totalidad de las partes del cuerpo humano comprende desde su crecimiento y la coordinación de diferentes movimientos y extremidades [1].

Motricidad final: Hace referencia a todas las acciones realizadas con las manos y los dedos a través de la coordinación mano-ojo [1].

Psicomotricidada: Es la unión de la motricidad con lo psíquico que significa que se producen cambios en la actividad psíquica a través de los movimientos. Uno de los objetivos principales de la Psicomotricidad es el descubrimiento del cuerpo humano y de la relación y comunicación que tienen las personas con el entorno que las rodea [2].

Psicomotricidad en el adulto mayor

Para poder potenciar esta habilidad en los adultos mayores se requiere realizar una serie de ejercicios de forma grupal en los que incluyan una parte de actividad física, por ejemplo, la imitación de movimientos corporales que implica la inclusión de la parte de la memoria, cognitiva y auditiva al escuchar las indicaciones dadas, además de fomentar la motivación tanto individual como grupal [3].

Beneficios de la pintura en Adultos Mayores

Los beneficios de la pintura en adultos mayores van desde el poder mejorar su salud mental ya que permite desarrollar su paciencia y la concentración [4], además que ayuda como una terapia de relajación en donde se pueden constatar los siguientes aspectos:

Mejora la autoestima: Puesto que fortalece la autonomía personal y su independencia lo que permite que sean más seguros de sí mismos.

Mejora la motricidad: Ya que brinda diferentes estimulaciones cerebrales, lo que ayuda a mejorar la motricidad fina y con ello pueden realizar diferentes movimientos y acciones.

Comunicación: A través de la pintura, las personas adultas mayores pueden expresarse de mejor manera mejorando su comunicación y con ello su capacidad de relacionarse socialmente.

Estimulación cerebral: Los adultos mayores a través de la pintura trabajan sus capacidades viso espaciales lo cual representa una terapia que puede ayudar a prevenir la enfermedad conocida como el Alzheimer [5].

Colores que benefician a la capacidad visual de un adulto mayor: Según la opinión de un especialista en fisioterapia, los colores que resultan llamativos para las personas de la tercera edad son el rojo, verde y azul pues son fáciles de reconocer y no causan cansancio visual.

Beneficio de las órdenes auditivas con el sistema de voz que se integradas en el videojuego: El audio que se emplea en los juegos y en el menú principal, tiene como objetivo dejar claro lo que el jugador necesita hacer con respecto al reglamento del juego, o los pasos necesarios para empezar a jugar. Las personas de la tercera edad necesitan que les hablen lento y con voz alta para que puedan escuchar, la edad afecta a su sistema auditivo, por lo tanto, el audio que se empleó, se acopla perfectamente a lo que el adulto mayor necesita.

Beneficio de los videojuegos en la motricidad fina en adultos mayores:

En cada uno de los juegos propuestos, se realizan ejercicios básicos, como, por ejemplo:

- Abrir y cerrar la mano.
- Movimientos de brazos.
- Estimulación de los dedos.

También, se hace uso de las capacidades cognitivas: Capacidad de memorizar. Concentración Comprensión del juego.

Python

Es un lenguaje de programación libre, este tiene una gran cantidad de librerías muy útiles, entre ellas se encuentran librerías especializadas en la tecnología hand tracking como es la de OpenCV, la cual es unas bibliotecas de visión artificial de código abierto con aprendizaje automático, esta biblioteca contiene más de 2500 algoritmos optimizados para el para el aprendizaje automático, además de la visión por computadora clásica y de última generación. Este tipo de algoritmos generalmente son utilizados para detectar y reconocer rostros, identificar objetos, clasificar acciones humanas en videos, rastrear movimientos de cámara y objetos en movimiento, extraer modelos 3D de objetos, producir nubes de puntos 3D de cámaras estéreo, encontrar imágenes similares de una base de datos, eliminar los ojos rojos de las imágenes tomadas con flash, seguir los movimientos de los ojos, reconocer un determinado escenario y establecer marcadores para superponerlo con la realidad aumentada, etc [6].

Hand Tracking aplicado a Python

El hand tracking aplicado a Python es el reconocimiento por medio de inteligencia artificial de las manos en un entorno tridimensional, en el caso de hand games, se requiere un reconocimiento de puntos específicos de la mano.

Media Pipe

Es una librería de código abierto de Google Open Source, especializado en hand tracking, la cual permite un reconocimiento de la palma de la mano con el fin de obtener 21 puntos clave de la misma denominados hand landmarks, que representan coordenadas "x" e "y" del plano cartesiano y son los nudillos, flexiones, etc [7].

Figura 1
Puntos de referencia de la mano otorgados por Media Pipe

0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP

En la Figura 1, se puede observar el gráfico referencial de los puntos de la mano. El controlador de movimientos se basa en los puntos 0, 8, 9 y 5 de la mano, los cuales integran las librerías de Python conjuntamente con Numpy que es una librería adicional que permite la inserción de matrices bidimensionales rápidas y versátiles, las cuales se utilizan dentro de las matrices de los puntos que ofrece Media Pipe.

Ctypes

Permite traer funciones externas a Python desde el lenguaje de programación C y con lo cual se pueden realizar llamadas de DLL o bibliotecas compartidas, una de estas funciones permite saber el tamaño de pantalla del sistema en el que se está ejecutando el controlador, lo que hace que el juego sea adaptable a cualquier pantalla.[8]

Math

Permite el acceso de funciones matemáticas definidas en el estándar del lenguaje de programación C, estas librerías dan soluciones para poder resolver teorías de números, además de funciones de representación, logarítmicas, exponenciales, trigonométricas, hiperbólicas, especiales, constantes y de conversión angular [8].

Mouse

Mouse es una librería de Python destinada a controlar el puntero dentro de la pantalla similar al uso del mouse, esto incluye emular los movimientos como pulsar clic derecho, izquierdo y medio. Se pensó usar al principio pyautogui que es otra librería con más funciones que la de mouse, pero debido a varios errores se optó por esta librería.

Coordenadas en pantalla

El objetivo de las librerías Media Pipe, Ctypes y Math es la transformación de las coordenadas que la cámara capta en la mano y las procesa en la pantalla, estas se pueden constatar cuando se dibuja un rectángulo, tal como se presenta a continuación; Figura 2:

Figura 2
Captura de pantalla de prueba realizada con el controlador
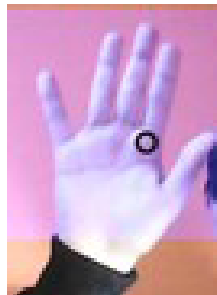
Emulación del mouse

El funcionamiento de todo el controlador se basa en el reconocimiento de los puntos 5, 0, 9 y 8 de la mano (hand landmarks INDEX-FINGER-MCO, 0. Wrist, 9.MIDDLE-FINGER-TIP y 8.IDNEX-FINGERPIP), para el movimiento del puntero en pantalla, se acogieron las coordenadas del punto 5 y se redujeron a las del rectángulo

azul, que a su vez se transforman en coordenadas de la pantalla, para las acciones del clic se trazaron dos líneas entre el punto 8 y 0, y el punto 9 y 0, a continuación de un condicional que cumple "Si la línea 8-0 es de menor tamaño a la línea 9-0 se procede a dar un clic o se mantendrá el clic dependiendo del tiempo que tomó esta acción"[8].

Figura 3
Controlador sin clic

Figure 4
Controlador dando clic
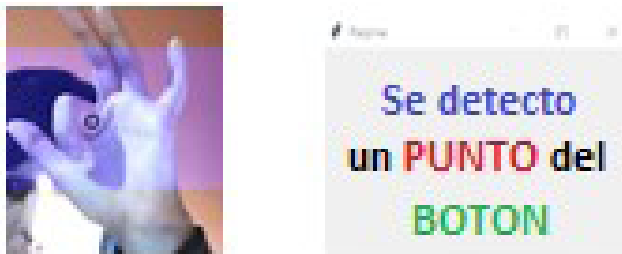
Unity

Es una herramienta que se utiliza para el desarrollo de videojuegos, para diferentes tipos de plataformas (PC, Consolas, Celulares). Se realiza por medio de un editor visual y programación por scriptings,

de tal manera que se consiguen resultados profesionales.[9] Siendo el principal software para desarrollar HAND GAMES, las funciones que ofrece Unity son multi-diversas, básicas para desarrollar un juego. [10]

Unity Hub

Se usa para activar licencias y administrar la cuenta Unity ID. Una vez que se inicia sesión con la cuenta de Unity, se accede fácilmente a los proyectos de Unity tanto locales como remotos [11]. Se almacenan los proyectos en los que estamos trabajando, y en caso de que haya una colaboración, podemos compartir el mismo proyecto para que todos podamos desarrollarlo.

Visual Studio

Visual Studio es un panel de inicio interactivo que se utiliza para editar, depurar y compilar código, entre otras más características que facilita el proceso de desarrollo de software con el lenguaje de programación C.

Visual studio 2022 ofrece características especiales para el desarrollo de Unity, como el manejo del lenguaje C que es el usa el editor de Unity. De tal manera que cada script que necesitaron los juegos, fue desarrollado en esta plataforma [12].

Visual Studio Code

Es un editor de código, compatible con casi todos los lenguajes de programación [9], además ofrece las herramientas necesarias como diseñadores, editores, depuradores, uno de los lenguajes de programación para los que puede llegar a ser útil es Python, ayudando en gran medida a el trabajo del controlador del juego [12]. Lo usamos para programar la estructura del controlador con las extensiones que ofrece (Python) [12].

Desarrollo del Juego

Protocolo Experimental

Dentro de esta etapa se realizó una entrevista a una especialista en fisioterapia en adultos mayores de la asociación de las Damas Salesianas de Cuenca Ecuador, la Licenciada Diana Carolina Quezada Zhinin, con el fin de obtener una opinión profesional, en donde se obtuvieron diferentes datos, los cuales apoyaron al diseño y desarrollo del videojuego empezando por la indicación de los colores de fondo y escenarios en los que se recomienda utilizar tonos pasteles o cálidos para que no afecte a la capacidad visual de las personas de la tercera edad. Otras de las indicaciones fueron la de inclusión de mensajes de retroalimentación en los que se presente dependiendo al puntaje obtenido, el respectivo detalle para el control del progreso de la persona además para constatar su interés en el videojuego, otro aspecto a considerar es el de las imágenes a utilizar, lo cual se recomienda que sean figuras básicas de manera que las personas de la tercera edad las puedan comprender.Para poder medir el progreso de la persona en cuanto al uso del videojuego como herramienta de apoyo de terapia para apoyo a la motricidad, la especialista sugiere tomar en cuenta tanto los aciertos como errores que se produzcan una vez finalizado el juego, además de la velocidad de respuesta de los jugadores. Tomando en cuenta las recomendaciones de la especialista se desarrolla el videojuego, cuyo diseño incluye colores cálidos y diseños básicos fáciles de comprender, tal como se presenta en el diseño de la portada.

Figura 5
Portada del Juego - HANDS GAMES

Para el diseño de las interfaces de los diferentes niveles del videojuego, se ha considerado la arquitectura que consta en el siguiente diagrama (Figura 6):

Figura 6
Diagrama del Juego
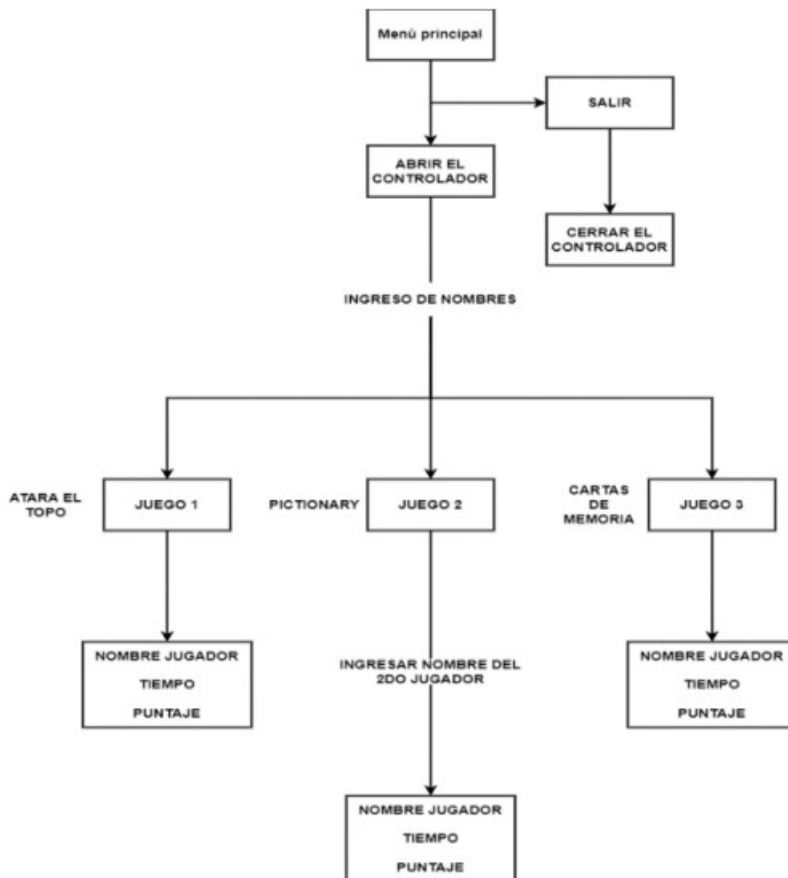
Cada una de las partes del diagrama representa las diferentes interfaces gráficas que conforman los niveles del videojuego, las cuales se detallan a continuación:

Inicio del programa:

Al ejecutar el programa, se crea una consola que empieza a ejecutar el controlador, después de la apertura del juego.

Menú Principal:

Dentro de esta interfaz, se encuentran dos botones en la pantalla. El primer botón "JUEGOS", el cual dirige a los diferentes juegos que dispone el programa en la opción Selección de Juegos. El segundo botón "SALIR", cierra el programa y el controlador de Python.

Selección de Juegos:

En la interfaz de selección de juego se despliega un pequeño cuadro de texto, este sirve para ingresar el nombre del jugador, con la validación de que debe cumplir más de cuatro caracteres, una vez ingresado se presentan tres botones en la parte inferior de la pantalla, con los cuales se podrá ingresar a los tres distintos juegos. Adicionalmente se incluye un pequeño botón para regresar al menú principal. Las opciones de los diferentes juegos son los siguientes:

Atrapa el Topo (Juego 1): Se basa en el juego tradicional de golpear a los topos con el uso de un mazo, sin embargo, al aplicar el concepto de hand tracking se utiliza la mano, la cual se presenta ante la cámara digital que reconoce los movimientos y se puede atrapar a los topos que aparecen en pantalla a través del movimiento que consiste en abrir y cerrar la mano, este movimiento permite reforzar la motricidad fina, además la capacidad cognitiva, ya que se aplica la concentración y agilidad mental. subsubsectionDibuja y Pintura (Juego 2): El juego de pintura se basa en el popular juego de pintura "Pictionary", para su uso,

se requieren entre 2 a 4 jugadores, siendo 4 lo óptimo para su desarrollo, cuando se tienen dos personas, el juego se divide en dos jugadores, uno es el dibujante y el otro es el que adivina lo que el primer jugador está dibujando, si el segundo jugador logra adivinar lo que se dibuja antes de que termine el tiempo, el segundo jugador gana un punto, si el segundo jugador no logra adivinar lo que el primero dibujó antes de que termine el juego, el primer jugador gana un punto y se continuará hasta una impuesta cantidad de puntos. La pintura requiere de movimientos precisos y finos, por lo que uno uso que se le puede dar es para mejorar la motricidad fina. Los movimientos que tiene que tiene que realizar mejoran tanto la destreza de los músculos como la de los huesos. También, otra manera en la que ayuda es estimulando ambos hemisferios del cerebro; esto gracias a que se emplean tanto las capacidades creativas como las lógicas. Lo más optimo es jugarlo en un grupo de 4 personas, la mecánica cambia de esta manera, se forman grupos de 2 jugadores, con jugadores 1 y 2, cuando empieza la partida el jugador 1 del equipo 1 debe dibujar lo que se le pide y el jugador 2 tiene que adivinar lo que su compañero dibuja, si los dos jugadores lo logran ganan un punto, caso contrario el otro equipo deberá ganar un punto, luego será turno del jugador 2 y se continuará en hasta una impuesta cantidad de puntos.

subsubsectionCartas de Memoria (Juego 3): Este juego es muy reconocido por las personas que les gusta jugar con cartas, sin embargo dentro de este videojuego se propone una manera más interactiva las personas de la tercera edad esto ayuda a la motricidad fina y a la memoria de la persona este juego se divide en 4 figuras (luna, cuadrado, estrella, rombo) son figuras sencillas que ayuda a la memoria empleando así una mejora en el futuro.

Figura 7: Figuras Cartas Memoria; se realizaron la elección de las cuatro figuras antes presentadas ya que son fáciles de comprender, utilizar y poseen colores manejables.

Figura 7
Figuras Carta de Memoria

Resultados

Para la obtención de resultados que comprueben el fin del proyecto se realizaron pruebas de funcionamiento del software en un ambiente real dentro de la Unidad Educativa Técnico Salesiano con la participación de catorce personas adultos mayores de un rango de edad de 59 a 81 años, los cuales interactuaron con los diferentes niveles del videojuego. Para la interpretación de los resultados se ha adaptado un método de calificación a través del puntaje final obtenido cuyo detalle se presenta en la Figura 8.

Dependiendo del puntaje obtenido en los juegos, se realiza un análisis con respecto a los intervalos planteados. De tal manera que se pueda ver el nivel de progreso. (Existen 5 niveles: Muy Preocupante, Preocupante, Normal, Bien, Excelente).

0 - 5 Puntos: Muy Preocupante. El resultado es extremadamente bajo, al paciente se le va a dificultar realizar actividades cotidianas, por lo que se recomienda asistir a terapia de

6 - 11 Puntos: Preocupante. El puntaje es bajo, pero sus movimientos motrices finos se pueden trabajar más para evitar cualquier pérdida de movimientos.

11 - 16 Puntos: Normal - (No hay Avance). El puntaje está en un estado neutro, no hay avances, ni empeoramiento, sin embargo, con el tiempo puede ir perdiendo esa movilidad, entonces, es necesario reforzar los movimientos motrices finos y psicomotrices que ofrece el juego.

16 - 21 Puntos: Bien (Existe un Avance). El puntaje que obtiene el jugador es muy bueno, eso representa que no tiene mayores problemas con la motricidad fina, sin embargo, debe realizar diferentes ejercicios para mejorar la movilidad.

+22 Puntos: Excelente (El avance es muy extenso). Este rango de puntaje representa que el avance es significativo por lo tanto no existen inconvenientes con los movimientos motrices finos, sin embargo, es importante siempre mantenerse activo con los ejercicios para reforzar los movimientos motrices. Basados en el protocolo experimental planteado, se obtuvieron los siguientes resultados descritos en la tabla 1.

Figura 8
Método de interpretación del puntaje obtenido

Tabla 1
Registro de los puntajes obtenidos de las personas
a las cuales se realizaron las pruebas.

Nro.	Nombre	Apellido	Puntaje Obtenido	Edad	Estado
01	Ángel	Lovato	13	61	Normal
02	Cristina	Brito	16	56	Normal
03	Gustavo	Zuñiga	12	63	Normal
04	Adolfo	Farfán	14	65	Normal
05	Elisa	Guerrero	5	59	Normal
06	Lope	Muñoz	15	86	Normal
07	José	Andrade	16	74	Normal
08	Joaquín	Castro	14	89	Normal
09	Roberto	Vera	16	57	Normal
10	Ándrea	Illescas	12	64	Normal
11	Pedro	Vera	18	86	Normal
12	Carlos	Castro	23	56	Normal
13	Andrea	Pesantes	19	76	Normal
14	Ariel	Gonzalez	6	81	Normal

De la tabla presentada se puede observar que los puntajes finales obtenidos más bajos van de 5 a 6 puntos, lo que significa que hay dos personas que requieren mejorar su motricidad fina a través de ejercicios recomendados por un especialista en el área de fisioterapia, sin embargo, las 12 personas restantes presentan un puntaje entre 12 a 19 lo que representa que no presentan mayores inconvenientes en su motricidad fina, por lo que únicamente se recomienda realizar ejercicios básicos Las reacciones que los jugadores presentaron ante el uso del videojuego fueron al inicio confusión y curiosidad, sin embargo luego se constató que hubo más interés, lo que les llevó a una mejor colaboración y comprensión de

cómo debían interactuar con cada uno de los niveles del juego, al final se comprobó que el proyecto tuvo un gran nivel de aceptación, pues las personas que pudieron interactuar con él reaccionaron de manera favorable ya que presentaron mayor interés por la tecnología, realizando constantes preguntas sobre su funcionamiento y sugiriendo mejoras.

Evidencia Fotográfica

Figura 9
Primer Jugador: Ángel Lovato

Figura 10
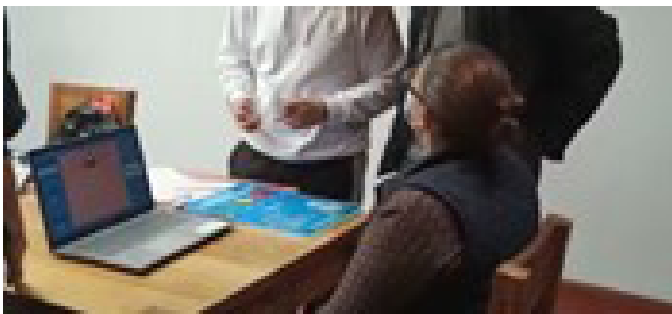**Segundo Jugador: Cristina Brito**

Figura 11
Tercer Jugador: Gustavo

Figura 12
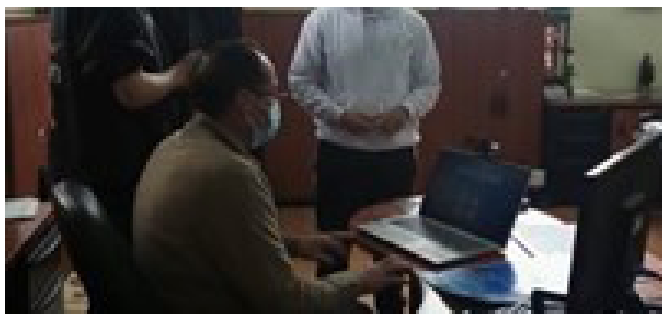**Cuarto Jugador: Adolfo Farfán**

Conclusiones

Una vez implementadas todas las herramientas, se puede lograr un software totalmente funcional con una gran versatilidad, ya que funciona en cualquier computador, requiriendo únicamente una cámara

web para su funcionamiento, dispositivo que viene incorporado en la mayoría de computadoras y laptops, el software de Hand Games también se consolida como una base para la creación de aún más juegos de motricidad incluso psicológicos abarcando, por su controlador basado en el movimiento del mouse. A pesar de que muchas personas mayores no están acostumbradas a la tecnología, el juego de Hand Games ha logrado encajar perfectamente en las personas con su control simple y sencillo, acompañado de una interfaz fácil y amigable para el usuario. Después de la etapa de pruebas, se puede concluir que el mejor ambiente para jugar a Hand Games es en un ambiente abierto, o por lo menos con suficiente espacio para evitar que la mano del paciente tape la interfaz del juego, también un ambiente con una luz media que permita reconocer la mano del paciente perfectamente es muy importante, ya que, si estos requisitos no se cumplen, el juego puede a veces no reaccionar.

Trabajo a Futuro

Planteamos la idea de implementar más juegos, para así mejorar el proyecto. De igual manera, mejorar los diseños y animaciones para una interacción más amigable. HANDS GAMES está diseñado para las personas de la tercera edad, por lo tanto, el objetivo principal es que sirva de ayuda en centros geriátricos, ancianatos, etc. Para poder ejecutar el controlador de la mano es necesario tener instalado Python y algunas de sus librerías, por lo que se planteó implementar un ejecutable de Python, con el objetivo de que no sea requerido por el usuario descargar las librerías manualmente de Python, si no, que todo venga guardado en un solo archivo. Se puede desarrollar la misma dinámica para aplicarse en diferentes edades de tal manera que tengamos una base de información variable que pueda desarrollarse para diversas interpretaciones en las áreas que puedan intervenir en el desarrollo de la investigación de la salud humana.

Agradecimiento A cad uno de las personas que ayudaran en el desarrollo de este estudio, a las entidades educativas secundarias donde su organización fue capaz de tomar decisiones orientadas y comprome-

tidas con planes de investigación, innovación y desarrollo que les permita ser evolutivos y adaptables en esta sociedad globalizada, contando con el compromiso del plantel docente siempre dispuesto al aprendizaje.

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Sistema para Apoyar el Entrenamiento Físico Multitarea con base a Estímulos Visuales

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Abstract

This work describes the development of a prototype for a multitask training support system based on visual stimuli. The prototype's architecture includes a microcontroller, touch sensors, an array of RGB LED lights, a LoRa module, a Bluetooth module, a battery charging source, and a mobile application. The system allows for data recording to create athlete profiles, schedule training routines, and acquire response time information for coach evaluation. To validate the system, tests were conducted with soccer and basketball players, and promising results were obtained regarding the use of technology in their training, as assessed through System Usability Scale (SUS).

Keywords

Microcontroller · LoRa · SUS · visual estimuli · fitness technology.

Introducción

La práctica de deportes a nivel profesional exige el desarrollo de habilidades físicas y mentales, más allá de las de una persona que realiza deporte amateur. Los deportistas, entrenadores y preparadores físicos siempre buscan nuevos métodos para mejorar las habilidades visuales y visomotoras con programas de entrenamiento [1].

Desde hace algunos años, a nivel profesional se están empleando sistemas para entrenamiento con luces que se pueden programar para rutinas con estímulos visuales que permitan mejorar los tiempos de reacción, que es un indicador importante en la práctica del entrenamiento deportivo [2], [3]. Sin embargo, limitaciones como el uso de sistemas inalámbricos de corto alcance, baja duración de las baterías y el no contar con aplicaciones móviles para la programación de rutinas y el monitoreo de datos pueden crear desconfianza en el empleo de tecnología en la práctica deportiva. Actualmente, la tecnología LoRa (del inglés "long range") está siendo empleada en apliciones de internet de las cosas por ser de bajo consumo, de largo alcance y con capacidad de recepción que le permite trabajar con interferencia de ruido de manera efectiva [4]. Estas características son importantes para el desarrollo de dispositivos para entrenamiento deportivo porque permiten ampliar las áreas de cobertura y planificar rutinas de entrenamiento para diferentes deportes.

En este documento, se describe el desarrollo de un prototipo de un sistema inalámbrico para entrenamiento físico multitarea basado en estímulos visuales para apoyar la preparación de deportistas usando tecnología LoRa, módulos con luces RGB, sensores de contacto y una aplicación móvil. Además, se presentan los resultados obtenidos de pruebas del prototipo que se realizaron con deportistas de las disciplinas de básquet y futbol con resultados a una evaluación SUS (del inglés System Usability Scale) satisfactorios.

Materiales y Métodos

Hardware y software

El prototipo del sistema de entrenamiento físico multitarea incluye un circuito basado en un microcontrolador PIC18F46K42 para el control del hardware del sistema que incluye siete módulos con luces LED (MLED), un sensor de contacto por cada MLED, un módulo LORA (MLORA) REYAX RYLR896, un módulo Bluetooth HC-06 y baterías recargables de litio ion18650 8800 mAh/4.2 V. El programa del microcontrolador permite gestionar la información de cada sensor de los MLED a través de rutinas maestro/esclavo. Para la protección de la batería de litio (Figura 1), se empleó un circuito electrónico que gestiona la forma de descarga de las baterías; entregando un voltaje de forma eficiente con regulación del consumo de corriente, reduciendo así el consumo de la batería de los MLED.

Figura 1
Circuito de conexión de la placa de protección de la batería.
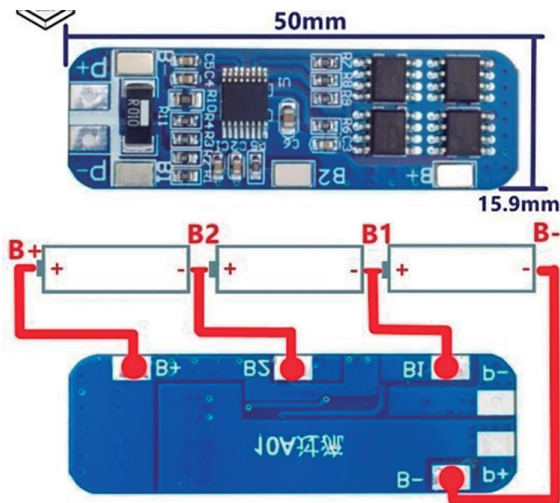
En la Figura 2 se pueden apreciar la placa de cada MLED.

La estructura externa de cada MLED (110 mm de diámetro y 55 mm de alto) y la base están elaborada de PVC (poli cloruro de vinilo). En la parte superior se colocó una tapa de acrílico y un disco de seguridad para formar una sola fuente de luz con iluminación completa a partir de los leds de la placa. El disco permite sellar herméticamente el MLED para que sea resistente al agua e ideal para utilizar el prototipo en diferentes ambientes. Cada MLED cuenta con un interruptor de encendido, un puerto para cargar las baterías y un sensor de contacto sobre el disco de seguridad, que es un pulsante con el cual interactúa el jugador que realiza el entrenamiento con el sistema. En la figura 3 se pueden observar un MLED ensamblado.

Figura 2
Placa del prototipo que incluye el módulo LoRa,
el DIP Switch asigna un número a cada MLED y en las borneras
se conectan las baterías y el gestor de carga.
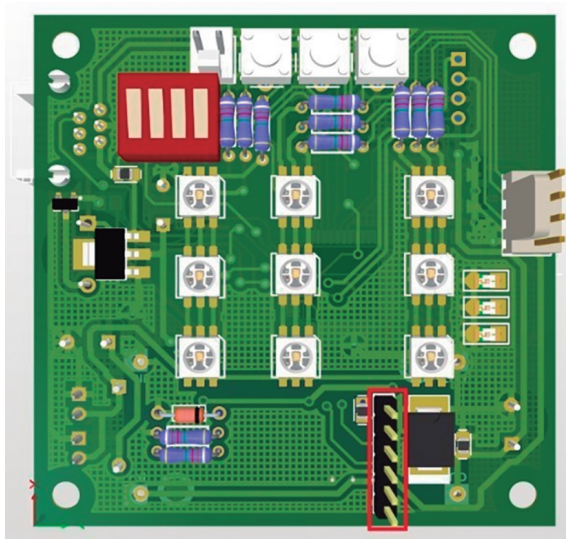
Figura 3
MLED (a) Dimensiones de la carcasa; (b) Modulo ensamblado.
Se encuentra marcado en rojo el sensor de contacto en el dispositivo.

(a)
(b)
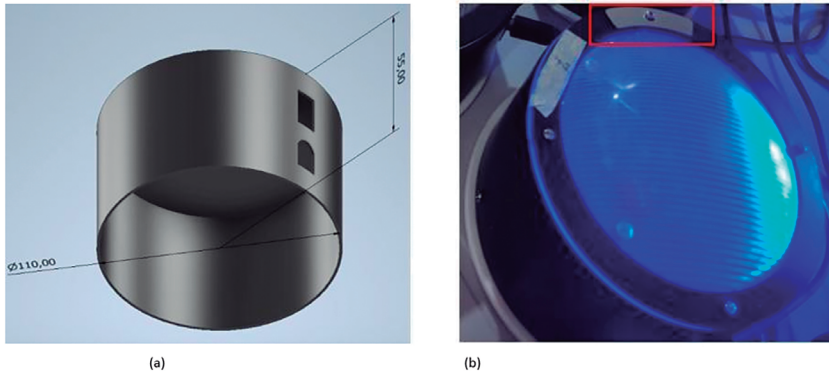
Se desarrolló una aplicación móvil (App) en Android Studio que se llamó UPS FIT LIGTH (ver Figura 4(a)) para programar rutinas de entrenamiento seleccionando el color de los MLED y el tiempo que deben estar activados (ver Figura 4(b) y (c). La App se enlaza únicamente con el dispositivo maestro del sistema mediante conexión Bluetooth.

El microcontrolador direcciona de esta manera la información del color y el tiempo de activación escogidos además de transmitir el estado de carga de la batería a la App.

En el diagrama de la Figura 5 se esquematiza el proceso funcionamiento del prototipo UPS FIT LIGTH, partiendo desde la configuración en la aplicación móvil que se enlaza únicamente con el dispositivo maestro del sistema mediante Bluetooth.

Figura 4
App UPS FIT LIGTH (a) Menú´; (b) Selección del color del MLED;
(c) Estado de batería de los MLED; (d) Perfil de participante.

(a)   (b)   (c)   (d)
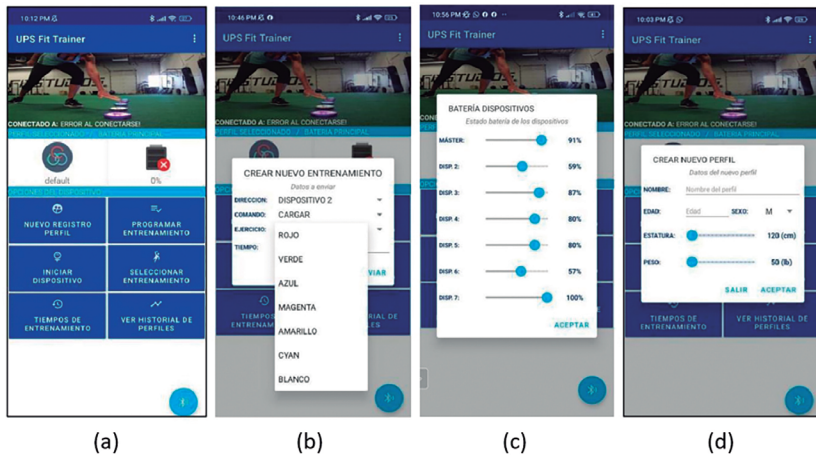
El dispositivo maestro recibe la señal y la procesa en el microcontrolador. El microcontrolador puede ejecutar dos subrutinas, para ser maestro o esclavo. La subrutina maestro se encarga de tomar la trama recibida por Bluetooth y la envía al MLORA maestro para su transmisión. Los MLORA de los esclavos se encargan de recibir la trama de envío. La subrutina esclavo se encarga de ejecutar un comando respuesta, pidiendo el estado de cada uno de los dispositivos esclavos. Los estados se refieren a los tiempos cronometrados almacenados y a los estados de la batería. La conexión Bluetooth enlaza la unidad maestro con el teléfono móvil y la conexión LoRa enlaza la unidad maestro con el resto de MLED. De esta manera es posible extender el número de MLED enlazadas al maestro, para extender el sistema a un número de 15 unidades. La Figura 6 esquematiza la navegación a través de la App hasta que la señal Bluetooth es enviada al prototipo. Previo a la inicialización de la App, se vincula el teléfono móvil con el prototipo a través de las configuraciones Bluetooth del teléfono.

Una vez que se logra la conexión entre el teléfono y el sistema, se procede a iniciar la aplicación UPS FIT TRAINER. Dentro de la aplicación se cargarán los dispositivos Bluetooth previamente vinculados. En esta lista aparecerá el dispositivo Bluetooth LoRa. Para iniciar la sesión de entrenamiento se debe crear un perfil de usuario valido y para ello se deberá colocar nombre, edad, estatura y peso (ver Figura 4(d)). La aplicación permite seleccionar rutinas precargadas o programar una sesión nueva. Una vez cargado el entrenamiento se procede a enviar la orden al dispositivo maestro para iniciar la sesión. La App permite recopilar los datos del número de aciertos y rapidez de respuesta, la duración de las sesiones de entrenamiento, el progreso de los entrenamientos y el perfil del jugador.

Figura 5
**Diagrama de bloques maestro – esclavo.**
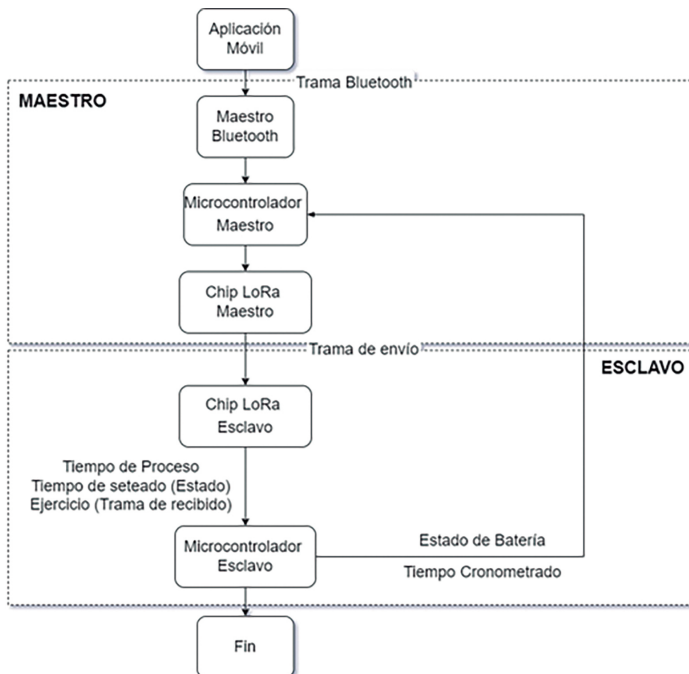
Pruebas

Para verificar que la distancia de alcance del sistema permita el trabajo en áreas útiles para práctica deportiva se programó una rutina considerando cubrir una cancha de futbol sintético de 75m x 108m. Para verificar la duración de la batería se realizaron sesiones de entrenamiento con todos los MLED encendidos durante 4 horas y posteriormente se registraron los porcentajes de carga de cada dispositivo que se muestran en la App. Cada uno de los MLED de luces se sometieron a mediciones de consumo energético para determinar la corriente mínima que consume cada dispositivo con cada color disponible de los leds. Para evaluar la aplicación móvil se realizaron pruebas para verificar la creación y selección correctas de los perfiles de usuarios. Se determinó además el tiempo que tarda en cargar la aplicación en tres modelos de teléfonos y el consumo de batería promedio de los teléfonos. Para calcular los valores de descarga de batería de un teléfono móvil por el uso de la App se utilizó la aplicación durante 60 min y se registraron los datos de batería al inicio y al final de este periodo en tres modelos diferentes de teléfono móvil. Estas pruebas son necesarias para comprobar el perfecto funcionamiento de la aplicación.

Se realizaron además pruebas de campo del dispositivo con deportistas de básquet y futbol. En las pruebas de básquet participaron 8 deportistas (edad 23,5 ± 6,4 años) y en las de futbol participaron 16 deportistas (edad 20,0 ± 3,7 años). Se trabajó con protocolos diseñados por un entrenador para cada disciplina, con el objetivo de adquirir datos que les permitan evaluar la coordinación mano-ojo, agilidad, equilibrio y destrezas. Las pruebas de básquet inician con ejercicios de salto de cuerda, desplazamientos laterales y encesto que debían realizarse en 25s, 25s y 40s respectivamente cuando los MLED con presenten el color rojo, azul y verde. Posteriormente se realiza un ejercicio de velocidad, aquí cada deportista debe realizar un "burpee" y desactivar el módulo MLED que se le asignó ubicado a 2,5m. Se realiza a continuación un ejercicio de coordinación y reacción empleando un MLED que median-

te un sonido da la señal para realizar el rebote de la pelota y dar un pase al compañero para correr a desactivar el MLED. Finalmente se realiza un ejercicio en grupo con cuatro deportistas quienes de espaldas esperan la señal del MLED que le corresponde y realizan un pase al compañero que tiene su MLED encendido.

Figura 6
Diagrama de bloques aplicación – maestro.
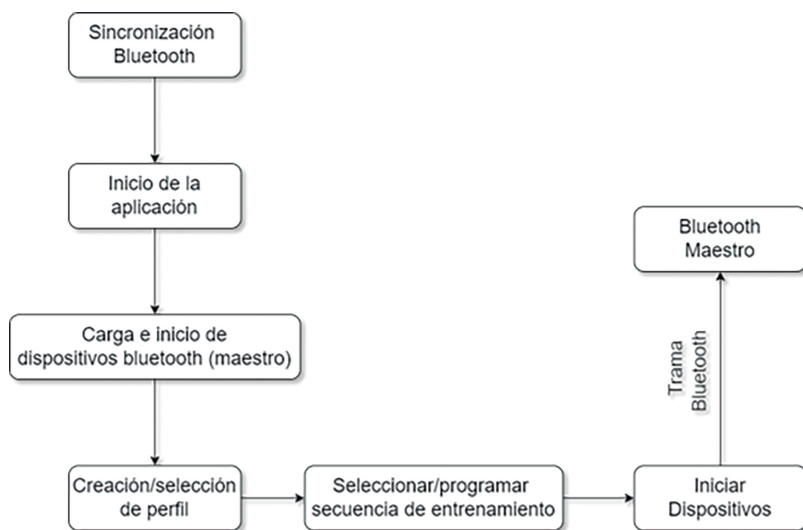
Las pruebas de futbol iniciaron con ejercicios de velocidad reacción para medir la capacidad de un jugador en toma de decisiones en el campo. La prueba se realiza con el grupo de 16 deportistas con los MLED configurados con un tiempo de encendido de 6 segundos y la activación en secuencia de los colores rojo y verde. Cada participante tiene asignado un color y cuando reciban la orden del entrenador deben correr y desactivar su módulo MLED. Mientras tanto el grupo practica pases entre ellos.

En la Figura 7 se visualiza parte de estas sesiones de entrenamiento.

Al finalizar las sesiones de entrenamiento se solicitó a cada participante y entrenador responder los cuestionarios correspondientes a los métodos SUS (del inglés System Usability Scale) y PSSUQ (del inglés Post Study System Usability Questionnaire) que se emplearon para evaluar la usabilidad del prototipo de entrenamiento "UPS FIT TRAINER".

Figura 7
Sesiones de entrenamiento (a) rutina que exige correr
para activar el MLED en básquet; (b) activación del MLED
en básquet; (c) rutina que exige velocidad para activar el MLED
en futbol; (d) activación del MLED en futbol.

(a)   (b)   (c)   (d)
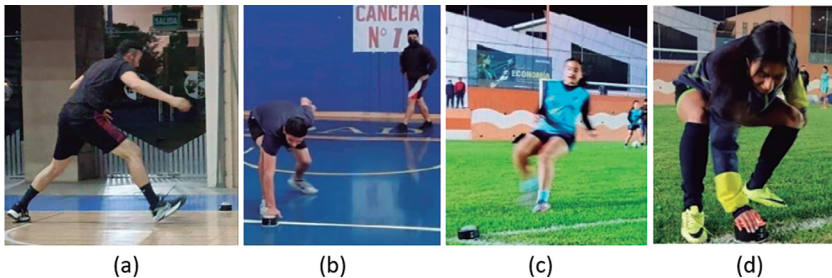
La escala de usabilidad SUS está basada en la evaluación de las respuestas de un cuestionario de 10 preguntas con una escala que va del 1 al 5 (E1: Fuertemente de acuerdo; E2: De acuerdo; E3: Neutral; E4: En Desacuerdo; E5: Fuertemente en desacuerdo), que se emplea para indicar el rendimiento de usabilidad en los aspectos de eficiencia, eficacia y facilidad de uso general de un sistema [5]. Las preguntas que se realizaron a los participantes fueron las siguientes: 1) "Pienso que me gustaría utilizar ese sistema con frecuencia"; 2) "Encuentro el sistema innecesariamente complejo"; 3) "El sistema me pareció fácil de usar"; 4) "Creo que necesitaría de ayuda de una persona con conocimientos técnicos para usar el sistema"; 5) "Creo que las funciones del sistema están bien integradas"; 6) "Creo que el sistema presenta muchas inconsistencias";

7) "Imagino que la mayoría de personas aprenderán a usar ese sistema rápidamente"; 8) "El sistema me pareció complicado de utilizar"; 9) "Me siento confiado al utilizar el sistema"; 10) "Necesite aprender muchas cosas antes de ser capaz de usar el sistema" [6].

El cuestionario PSSUQ es usado para evaluar la satisfacción del usuario en aplicaciones y en sistemas informáticos y una de sus ventajas es su replicabilidad en el transcurso de los an˜os [7]. PSSUQ utiliza la escala Likert de 7 niveles, la puntuación empieza con 1 (fuertemente de acuerdo) y termina con 7 (fuertemente en desacuerdo) y se utiliza para la valoración que tiene el usuario respecto a la aplicación. La evaluación de este cuestionario de 16 preguntas se divide en parámetros o subes calas como: a) SYSUSE (Utilidad del sistema) con puntajes promedio de las preguntas de 1 a 6; b) INFOQUAL (Calidad de información) con puntajes promedio de las preguntas 7 a 12; c) INTERQUAL (Calidad de la interfaz) con puntajes promedio de las preguntas 13 a 15. Se analizan las subes calas o parámetros porque brindan detalle de los diferentes factores que afectan al sistema [7].

Resultados

La corriente mínima que consume cada MLED se encuentra entre 80 mA y 90 mA, en estado de reposo. Cuando el MLED está encendido la corriente que se consume es de 15mA con los colores rojo, verde y amarillo y de 20mA con los colores azul, magenta, cyan y blanco. El voltaje es de 1,6V para el color rojo; 1,7 para amarillo; 2,4V para verde; 3V para azul; 3,4V para cyan y blanco y de 4,6 para el color magenta. Sobre el consumo de batería, se verificó que el prototipo permite un uso continuo de 4 horas de los MLED cuando los colores se escogen de manera aleatoria. Esto garantiza un nivel de batería adecuado para entrenamiento deportivo porque no es necesario cargar las baterías en medio de una sesión.

El tiempo promedio que se tarda en cargar la aplicación en un teléfono, es decir, desde que se abre la aplicación hasta que se muestra la primera interfaz que es la conexión con el modulo Bluetooth es de 1,95 s. Este tiempo es el adecuado para la aplicación, porque el tiempo recomendado es de 2 s. El consumo de batería promedio en un teléfono por el uso de la aplicación es de 8,66 %.

En la Tabla 1 se muestran los puntajes obtenidos por los entrenadores que participaron de las pruebas. La puntuación media dada es de 94,16. Esta puntuación se encuentra dentro del rango mayor a 80,3, lo que indica una clasificación excelente y una calificación A.

En la Tabla 2 se muestran los puntajes obtenidos por los participantes de básquet. La puntuación media dada es de 84,28. Esta puntuación se encuentra dentro del rango mayor a 80,3, lo que indica una clasificación excelente y una calificación A. Esta calificación muestra que el prototipo del sistema está aprobado y es aceptable en el ´ámbito de usabilidad y satisfacción.

En la Tabla 3 se muestran los puntajes obtenidos por los participantes de futbol. En esta sesión la puntuación media dada es de 79,06. Esta puntuación se encuentra dentro del rango 68 a 80,3, lo que significa una clasificación buena y una calificación B. Esta calificación obtenida representa que es un prototipo admitido y es aceptable en el ´ámbito de usabilidad.

Table 1
Puntaje SUS de los entrenadores

Entrenador	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
1	1,00	4,00	1,00	5,00	1,00	5,00	1,00	5,00	1,00	5,00	97,50
2	1,00	5,00	1,00	3,00	1,00	5,00	2,00	5,00	1,00	5,00	92,50
3	1,00	3,00	1,00	5,00	1,00	5,00	1,00	4,00	1,00	5,00	92,50

Table 2
Puntaje SUS de los participantes de básquet

Deportista	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
1	2,00	4,00	2,00	5,00	2,00	4,00	2,00	4,00	1,00	5,00	95,00
2	1,00	5,00	1,00	2,00	1,00	5,00	1,00	5,00	1,00	2,00	85,00
3	1,00	5,00	1,00	5,00	1,00	5,00	2,00	4,00	1,00	5,00	95,00
4	2,00	4,00	1,00	3,00	2,00	3,00	1,00	5,00	1,00	4,00	80,00
5	1,00	4,00	1,00	4,00	1,00	4,00	1,00	1,00	3,00	5,00	77,50
6	2,00	2,00	1,00	3,00	2,00	3,00	1,00	5,00	1,00	4,00	75,00
7	2,00	4,00	1,00	5,00	1,00	5,00	2,00	4,00	2,00	3,00	82,50

Table 3
Puntaje SUS de los participantes de básquet.

Deportista	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
1	1,00	5,00	1,00	5,00	1,00	5,00	2,00	4,00	1,00	5,00	82,50
2	1,00	4,00	2,00	4,00	3,00	3,00	2,00	4,00	2,00	4,00	72,50
3	2,00	4,00	2,00	5,00	2,00	4,00	2,00	4,00	1,00	3,00	72,50
4	1,00	4,00	1,00	3,00	1,00	5,00	3,00	4,00	4,00	3,00	72,50
5	3,00	3,00	2,00	4,00	5,00	4,00	2,00	5,00	1,00	5,00	80,00
6	4,00	3,00	2,00	2,00	2,00	3,00	3,00	2,00	3,00	3,00	47,50
7	1,00	5,00	1,00	1,00	2,00	4,00	1,00	4,00	1,00	4,00	80,00
8	1,00	2,00	1,00	2,00	1,00	4,00	2,00	4,00	4,00	4,00	67,50
9	1,00	4,00	1,00	3,00	2,00	4,00	2,00	4,00	3,00	5,00	77,50
10	1,00	5,00	1,00	2,00	1,00	5,00	1,00	5,00	1,00	5,00	92,50
11	1,00	5,00	3,00	3,00	1,00	5,00	1,00	3,00	1,00	5,00	85,00
12	1,00	5,00	3,00	3,00	1,00	5,00	1,00	3,00	1,00	5,00	85,00
13	1,00	2,00	1,00	2,00	1,00	2,00	1,00	5,00	1,00	5,00	77,50
14	1,00	5,00	1,00	1,00	1,00	5,00	1,00	5,00	1,00	5,00	90,00
15	1,00	5,00	1,00	1,00	1,00	5,00	1,00	5,00	1,00	5,00	90,00
16	1,00	5,00	1,00	5,00	1,00	3,00	1,00	5,00	1,00	5,00	87,50

En el caso de la utilidad de la App (SYSUSE) la puntuación media fue de 1,00. Esto quiere decir, que el sistema tiene un nivel alto de confiabilidad según las opiniones de los entrenadores. Los entrenadores manifestaron su satisfacción, porque comentaron que la aplicación les pareció intuitiva y útil para monitorear la preparación y progreso de los deportistas, visualizar y guardar resultados para un análisis posterior; generar múltiples arreglos lumínicos de color y para poder seleccionar los dispositivos que se deseen utilizar en cada sesión de entrenamiento.

La puntuación media obtenida para la calidad de información (INFOQUAL) fue de 1,17. Este valor indica que la aplicación contiene la información necesaria para la programación de secuencias de entrenamiento en conjunto con el prototipo y para el desarrollo de actividades dentro de la aplicación como visualización de resultados. Los entrenadores opinaron que la información entregada por la aplicación móvil sobre los resultados del entrenamiento era concisa, ordenada e importante; información como el tiempo de reacción o rapidez de respuesta, número de aciertos y progreso de entrenamientos.

El valor promedio obtenido para la calidad de la interfaz (INTERQUAL) fue 1,00 dentro del análisis de datos. Este valor siendo más cercano a uno, asegura que la aplicación facilita la interacción correcta entre el prototipo, el teléfono y el usuario. Los resultados presentados, aseveran que la aplicación tiene un nivel aceptable de satisfacción y usabilidad. Sin embargo, los entrenados manifestaron que la aplicación aún tiene aspectos y herramientas que se podrían mejorar o incluir.

Discusión y Conclusiones

El 100% de los participantes de la disciplina de básquet encuestados, manifestaron estar conformes en el uso del dispositivo. El 57% indicó que están fuertemente de acuerdo y un 43% afirmó estar de acuerdo; por lo tanto, se puede decir que se cuenta con la aceptación de utilidad del prototipo como parte de sus entrenamientos.

Sobre si el sistema es fácil de manejar, el 43% está fuertemente en desacuerdo, otro 43% está en desacuerdo, el 14% indica que encuentra dificultades al usar el sistema. Por sus comentarios se sabe que esto se debe por la ubicación del sensor de contacto que puede provocar fallas al momento de tocarlo en rutinas rápidas. Se determinó que es necesario hacer ´énfasis en instrucción del entrenador para no tener dificultades al usar el sistema y culminar cada set de ejercicios realizados durante las sesiones. El 57% de los participantes mencionan no necesitar a un técnico o especialista para el manejo del dispositivo (43% está fuertemente en desacuerdo y 14% en desacuerdo). El 14% afirma necesitar a una persona con conocimientos técnicos para el uso del dispositivo y para finalizar el 29% menciona ser indiferente a esta interrogante. La totalidad de los participantes encuestados aseveran que las funciones del sistema se encuentran bien integradas (71% fuertemente de acuerdo y 29% de acuerdo), por lo tanto se puede confirmar la funcionalidad del prototipo.

A la consulta de si el sistema presenta muchas inconsistencias el 71% muestra su desacuerdo porque en el entrenamiento no verificaron inconsistencias, de esa manera el 57% está fuertemente en desacuerdo y el 14% en desacuerdo, mientras que un 29% manifiesta neutralidad. Las respuestas de esta pregunta reflejan que el sistema se encuentra de condiciones ´óptimas para su uso. El 100% de los encuestados (57% fuertemente de acuerdo y 43% de acuerdo) aseveran que el prototipo es de fácil aprendizaje y manejo. A la consulta de si el sistema fue complicado de utilizar, el 43% está fuertemente en desacuerdo, el 43% en desacuerdo, el 14% restante opina estar de acuerdo. El 86 % de las personas encuestadas se sienten seguras con el uso del prototipo en los entrenamientos (72% fuertemente de acuerdo y 14% de acuerdo). Por último, el 14% restante se mantiene neutro.

Sobre la pregunta de si se requieren conocimiento para el uso del sistema, el 43% de los encuestados están fuertemente en desacuerdo y el 29% en desacuerdo, por esta razón se puede deducir que para la mayoría de personas no es necesario tener conocimientos previos de dispositivos para entrenamiento similares al desarrollado para el uso del prototipo.

Sobre las respuestas de los deportistas de futbol se puede manifestar que el 75% indicaron total conformidad al utilizar el dispositivo, el 13% de los participantes indicaron conformidad, el 6% mostró una respuesta neutral y el 6% final demostró menor interés en dedicar tiempo al prototipo. Al ser consultados por su respuesta indicaron la preferencia por entrenar de forma tradicional.

El 69% de los participantes afirman que el sistema no es complejo. Desglosando este porcentaje, el 12% tuvo una respuesta neutral y el 19% indicó que el dispositivo presenta complejidad. Sus argumentos, al igual que el de los basquetbolistas indicaban que la ubicación del sensor de contacto complica el uso del sistema en algunos tipos de tareas de entrenamiento. El 87% indica que el sistema es de fácil uso y el 13% restante manifestó una respuesta neutral debido a que prefieren las indicaciones de un instructor o entrenador para aprovechar los beneficios del dispositivo y explotar el potencial de los jugadores en el entrenamiento.

El 19% niega necesitar ayuda del ingeniero a cargo del sistema para su manipulación. El 12% encuentra en común no necesitar de guía técnica sobre el prototipo. Por otro lado, el 25% de participantes se mostró neutral al mostrar pocos conocimientos técnicos sobre el tema. Un 25% menciona que se debería tener conocimientos sobre tecnología y el 19% restante afirma requerir total guía de personal técnico que se encargue de las operaciones durante el entrenamiento. Los participantes encuestados que representan los tres últimos porcentajes indican, que necesitarían la ayuda un técnico para solucionar problemas relacionados a la tecnología del dispositivo y reiteraron que prefieren la instrucción de un entrenador. El 57% afirma que las funciones del prototipo son las necesarias y que operan de acuerdo con sus exigencias. El 31% recalca esta afirmación mencionando las opciones de personalización. El 6% mostró una respuesta neutral y el 6% final afirma que el dispositivo no cuenta con las funciones adecuadas. Indican que el sensor debería estar ubicado sobre la tapa de acrílico y no sobre los bordes para poder activarlo con las manos y los pies.

El 75% de participantes afirma que el sistema no presenta inconsistencias de ningún tipo el 19% se mostró neutral y el 6% final menciona que el sistema tiene inconsistencias, debido a las dificultades que tiene el sensor para captar el toque de la mano, dentro de sets de ejercicios que requieren repetición.

Más de las tres cuartas partes de los participantes afirman la rápida adaptación al sistema. El 50% de afirma que los futuros usuarios encontraran fácil el usar el prototipo.

El 44% señala que es un dispositivo fácil de utilizar y un 6% concuerda con que el prototipo es complejo, mencionando el tamaño del sensor y los errores de medición que se generan por esto.

El 69% de participantes aseguró reconocer todas funciones importantes que el sistema de entrenamiento incluye para poder utilizarlo en sesiones personalizadas. El 13% de los usuarios indicó no sentir la necesidad del uso de los MLED en los entrenamientos por su tamaño. El 62% de participantes están completamente de acuerdo de que no se necesitan conocimientos previos para saber manipular un sistema de entrenamiento como este, mientras que un 19% decidió mostrar una postura neutral sobre esta afirmación.

El 66% de los entrenadores encuestados aseveran no encontrar al sistema complejo, el 100% afirma que el prototipo es fácil de usar. Justificando esta respuesta, argumentaron que el sistema presenta funciones elementales, básicas y precisas para el ´optimo y fácil uso. El 67% manifestó que no necesita explicaciones extra para intuir sobre el funcionamiento del sistema. El 100% concuerda en que las funciones del dispositivo son las necesarias e ideales para el progreso, acondicionamiento y preparación física de los jugadores, afirmando que las funciones se encuentran bien integradas para incluir el prototipo en sus entrenamientos. El 100% de los entrenadores se muestra en total desacuerdo al mencionarles que el dispositivo presenta muchas inconsistencias. El 67% indica que el sistema no representa un reto técnico y que

las personas aprenderán a usar el sistema en minutos, así como ellos lo experimentaron. El 67% indica que el sistema es fácil de usar, el 100% se muestra totalmente confiado con el uso e integración del dispositivo dentro de futuros entrenamientos. El 100% afirman que las indicaciones básicas entregadas por los ingenieros a cargo fueron claras, concisas y las necesarias para usar el sistema.

Se refleja como resultado favorable con un 100% de aceptación por parte de los entrenadores, argumentando que el dispositivo proporciona múltiples ventajas al momento de desarrollar los entrenamientos. Además, los tres entrenadores aseguran que con la práctica se lograría: una mejor agilidad del deportista, trabajar estrictamente coordinación mano – ojo – mente, mejorar tiempo acción y reacción ante un estímulo, toma decisiones correctas inmediatas bajo presión, En conclusión, el dispositivo puede emplearse para mejorar las habilidades y destrezas del deportista.

Por otra parte, con los resultados obtenidos del cuestionario PSSUQ se puede concluir que para los encuestados la App se encuentra en un nivel alto de satisfacción y usabilidad.

Si bien los resultados son satisfactorios es importante plantear un protocolo a largo plazo, para la evaluación del impacto de este tipo de tecnología en la mejora del rendimiento de los deportistas, para anticipar las acciones de su oponente y tomar decisiones oportunas [8]. El hardware puede ser rediseñado para realizar pruebas con deportistas de otras disciplinas que permitan plantear mejoras al sistema [9].

Por lo expuesto se concluye que se consiguió diseñar e implementar el prototipo de un sistema de entrenamiento físico multitarea basado en estímulos visuales para apoyar la preparación de deportistas. Es posible integrar los dispositivos con su App para sesiones de entrenamiento en áreas extensas como las requeridas en disciplinas como básquet y de futbol. Esta versión de sistema se desarrolló para brindar una alternativa accesible a dispositivos de entrenamiento de alta gama. Los puntajes

obtenidos del cuestionario SUS permiten concluir que el prototipo se encuentra en un nivel aceptable de satisfacción y usabilidad. Las sugerencias recibidas sobre las dimensiones y ubicación del sensor de contacto se considerarán para un rediseño de los módulos MLED, así como un estudio a largo plazo para evaluar el impacto de esta tecnología en el entrenamiento de básquet y futbol.

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