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Intelligent System for Tourist Guidance in Tumbes-Perú

Raúl A. Sánchez-Ancajima[1*], Miguel Jiménez-Carrión[2], Flabio Gutiérrez[3], Adriel O. Hermenegildo Alfaro[4], Edwar Lujan-Segura[5], and Jordan A. García Blas[6]

[1*]Universidad Nacional De Tumbes, Tumbes, Perú. rsanchez@untumbes.edu.pe, https://orcid.org/0000-0003-3341-7382

[2]Universidad Nacional De Piura, Piura, Perú. mjimenezc@unp.edu.pe, https://orcid.org/0000-0001-9632-5085

[3]Universidad Nacional De Piura, Piura, Perú. flabio@unp.edu.pe, https://orcid.org/0000-0003-0372-3864

[4]Universidad Nacional De Tumbes, Tumbes, Perú. ahermenegildoa@untumbes.edu.pe, https://orcid.org/0000-0001-5436-9696

[5]Universidad Nacional De Trujillo, Trujillo, Perú. elujans@unitru.edu.pe, https://orcid.org/0000-0003-0663-4189

[6]Universidad Nacional De Trujillo, Trujillo, Perú. jagarciab@unitru.edu.pe, https://orcid.org/0000-0002-1864-1661

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Abstract

An Intelligent System (IS) for Tourist Guidance was developed for the city of Tumbes, Peru. Considering the preferences of the tourist, the IS obtains the optimal route for the visit and provides a visit plan with schedules and times of stay in each place. It is an innovative hybrid system since it is complemented by two artificial intelligence techniques, a rule-based expert system and a genetic algorithm. The methodology for the implementation of the IS consisted of the collection of tourist, geographic, georeferenced information and photographs of 28 tourist places, grouped into Beaches, Nature, Adventure, Culture and Medicinal Sites, then the logical rules, the distance matrix and time of stay in each place were developed, and finally with the vehicle routing technique the genetic algorithm is implemented that allows obtaining the optimal route. The results indicate that the GA provides optimal solutions with an execution time of 5.6 seconds and zero errors. This contribution is very important for future work on tourist profiles and new tourist routes, since the intelligent system can be adapted for use in other cities.

Keywords: Intelligent System, Genetic Algorithm, Tourism, Vehicle Routing.

1 Introduction

Internet Tourism is one of the productive sectors with a great positive impact in the world, not only economically, but also with a high social and environmental impact, in this sense, (Hosteltur, 2024) compares tourism with sectors such as industry, agriculture, education, automotive and even banking,

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*Corresponding author: Universidad Nacional De Tumbes, Tumbes, Perú.

stating that tourism, in terms of its direct and indirect activities, generated around 9.8% of world GDP, above other sectors, a behavior evident until 2019.

Since 2020, due to the Covid 19 pandemic, Tourism worldwide declined due to the restrictions imposed on travel, however, the (World Tourism Organization, 2024) says that global tourism in 2023 has shown rapid recovery in all regions of the world, and even estimates that in 2024 it will reach the levels recorded before the pandemic (Dijana & Jovana, 2023).

Tourism related to nature, culture, the economy and lately with technology is considered a fundamental activity that includes a group of positive factors among the populations of the tourist destination, since it motivates and involves them to develop chains of services in accordance. to the requirements of tourists and visitors, in addition to caring for and preserving its heritage (Yu, 2021; (Sánchez-Ancajima et al., 2023).

In this relationship, the importance of tourism for the development of communities in the world grows (Liu et al., 2023), which means that any tourism development model today must be driven by tourism research (Surayyo et al., 2024). Therefore, it is necessary to review different research in the area of tourism and its important relationship with the economy (Liu et al., 2022), society and technology, which are the support and basis for our study (Sánchez-Ancajima et al., 2023).

Tourism is a sector that directly impacts the economic growth and development of a country, affects the growth of the gross domestic product, promotes business dynamism, generates jobs, becoming one of the economic activities that generates greater expectations, both at the level of governments and the population; The rapid and stable growth of the tourism sector generates the attention and interest of the academic community, which is why universities have incorporated the Bachelor's Degree in Tourism into their academic programs, and many others offer master's degrees and doctorates in this discipline, which has increased tourism research, reflected in the increase in articles published in high-impact scientific journals, gradually consolidating the scientific community in this field as well as its research (Vargas-Arana & Utia-Shapiama, 2020).

In the social aspect, (Coffey et al., 2024) reveal that individual and group experiences of vacation tourism, which they call self-expansion, cause greater physical and emotional affectivity, likewise, (Clissold et al., 2022) affirm that nature-based tourism is an alternative that provides a structured format that optimally facilitates well-being opportunities, thus, these investigations indicate that nature is a public health resource and in its results it promotes constant contact with nature for the lasting well-being of people and the planet; in this line, our research contributes to promoting the tourist attractions of the Tumbes region from a scientific approach by using artificial intelligence tools (Choi et al., 2022).

In the last decade, intelligent systems and in particular tourist recommendation systems are showing great importance when they combine big data technology and personalized advice, using methodologies that manage to solve the problem of information overload in various application domains such as e-commerce and e-tourism as can be reviewed in the works of (Liang, 2021; Seminario, 2021; Logesh et al., 2019; Du, 2021) additionally we can see the articles (Borrás & Moreno, 2014; Loureiro et al., 2020; Li et al., 2021; Sánchez et al., 2023) which exhibit similar methodologies to identify tourist resources and attractions to promote tourism in a certain city or geographic space using artificial intelligence.

In general, tourism has been, is and will continue to be an important factor as a driver of the economy in the world, having as an ally technology mainly related to artificial intelligence (Sun et al., 2023; Sun et al., 2022; Knani, 2022; Cao, 2022; Smirnov & Kudinov, 2021; Xiao, 2022; Wang et al., 2021; Baggio, 2020).

Expert Systems and Vehicle Routing (VRP) are some of the areas to create intelligent systems applied to tourism, for example, (Hussein & Aqel, 2015), developed in Jordan a rule-based tourism Expert System (ES) that helps to choose the best tourist package based on time, budget and preferences, likewise, (Halkiopoulos et al., 2021), develop an ES to recommend tourist destinations based on factors such as the type of tourist, countries of origin, the period of time considered, types of tourism (Farroñan & Salazar, 2017).

Regarding VRP applied to tourism, we can mention (Kar et al., 2023) who propose an optimized tourist itinerary recommendation system using a VRP approach with the aim of maximizing tourist destinations around a major city in India by taking the shortest routes, another example is the work of (Pei et al., 2022) who used VRP to optimize the tourist route in the Lushunkou district in China.

In Peru, expert systems have also been used to recommend tourist places; for example, (Fernandez et al., 2022) developed a rule-based ES to guide users of the tourist corridor in the provinces of Jaén, San Ignacio and Utcubamba (Peru); likewise, proposed an ES to promote tourism in the Lambayeque region (Peru), however, these systems do not use vehicle routing or a genetic optimization algorithm and are limited in the sense that they do not develop a visit plan for the tourist that indicates an optimal route and time of stay at each place; and our work is precisely interesting because it covers this gap by using the evolutionary meteorology of genetic algorithms to provide tourists with an optimal route according to their preferences (Praveenchandar et al., 2024).

As far as we know, in Peru no Intelligent System for tourist orientation has been developed that integrates the methodologies of expert system and vehicle routing through the genetic algorithm that allows obtaining the optimal route of the places to visit (Gustavo et al., 2024).

In the case of the Tumbes Region, favored by nature by having a warm climate practically all year round, in addition to being on the border with Ecuador as it is located in the north of Peru (Ministry of Foreign Trade and Tourism, MINCETUR, 2023), tourist information is disseminated through various media, the main one being IPerú, which is the official tourist information service of Peru, in addition to tourist guides provided by municipalities, regional government and tour operators, which provide information on attractions, routes, circuits, services, among others, there are also web pages of State institutions such as the (MINCETUR 2024), as well as private organizations (National Institute of Statistics and Informatics (INEI), 2022).

National and foreign tourists plan their trip months or weeks in advance, but the information presented by the aforementioned institutions is static and does not recommend places to visit according to the preferences of tourists, much less help to optimize the route of the places to visit (National Institute of Statistics and Informatics (INEI), 2022).

This problem makes visiting Tumbes for tourism purposes limited; it is expected that in many cases it will not satisfy the demands of tourists, therefore, alternatives must be created so that tourists can use applications with cutting-edge technology based on artificial intelligence that help them make decisions.

This paper proposes the Design and Implementation of an Intelligent System (IS) for tourist orientation in the city of Tumbes, which based on user preferences recommends places to visit and delivers their visit plan with schedules and times to stay in each place.

The IS proposes a hybrid methodology in the sense that it uses two intelligent modules, the first module is an ES that simulates a human expert in tourism, which based on user preferences recommends places to visit, this ES provides the information to the second intelligent module, which uses vehicle routing and a genetic algorithm to obtain an optimal visit plan.

To do this, the phases of Obtaining tourist information, System Design, System Implementation and System Validation were followed.

The article is structured as follows. The basic concepts are described in Section 2; the Design of the IS is described in Section 3; the implementation of the IS is described in Section 4; the validation of the IS is described in Section 5; Discussion and Results are described in Section 6 and conclusions are provided in the final section.

2 Basic Concepts

Artificial Intelligence (IA) has different areas, Machine Learning, Deep Learning, Generative Artificial Intelligence, Case-Based Reasoning, Expert Systems, Metaheuristics etc.

One of the first areas developed by AI are Expert Systems. They are applied when you want to develop systems that imitate or simulate a human expert in a specific domain, they can act as assistants to a human expert, in domains where experts are scarce or when you want to help many users in making decisions. for example, through web pages or mobile applications (Diana et al., 2020). An expert system may be considered an appropriate alternative when there is no algorithmic solution to a problem and rule-based expert systems are considered appropriate candidates to apply in this category of complex problems (Hossain et al., 2018; Hossain et al., 2019).

Expert System Definition (Castillo et al., 1997).

An ES can be defined as a computer system (hardware and software) that simulates human experts in a given area of expertise.

The main components of an ES are the knowledge base and the inference engine; The knowledge base stores the knowledge obtained from the expert or other sources and the inference engine makes the decisions (Prasad & Choudhary, 2021). Structure of an Expert System shown in Figure 1.

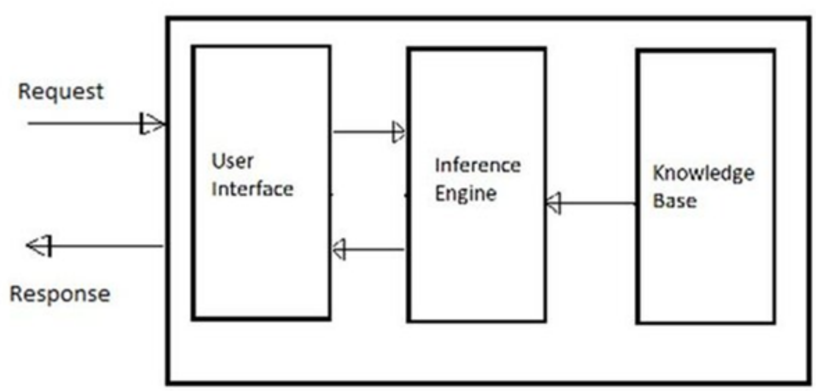

Figure 1: Structure of an Expert System (Prasad & Choudhary, 2021)

Depending on how knowledge is represented and what the inference engine is, there are different expert systems: rule-based ES, probabilistic ES and fuzzy ES (Castillo et al., 1997).

Vehicle Routing

In the Traveling Salesman Problem (TSP), the minimum duration of the journey between a set of cities and returning to the city of departure must be found, knowing that each city must be visited once.

For the last fifty years, TSP is one of the most important topics for exploring optimization problems in operations research. The TSP is a known combinatorial optimization problem, solved and open to research due to its complexity of resolution. The TSP is important because it serves as a basis for solving other problems such as areas of industrial planning, cargo logistics, the design of transportation routes or the cycle that a printed circuit board drill must follow, among others. The TSP is the basis for the Vehicle Routing Problem (VRP) and its variants. THE TSP has been solved, among others, through metaheuristic techniques, which are general algorithmic structures adaptable to many optimization problems, among the best known are Genetic Algorithms (Jiménez-Carrión et al., 2020), Colonias de Ants (Obando-Vidal et al., 2020), Optimization of Variable Meshes (Oviedo et al., 2018).

Genetic Algorithms

Genetic Algorithms (GA's) are methods that follow the Darwinian principle of living organisms applied to solve highly complex problems such as the classic traveling salesman problem (TSP), obtaining the routes that tourists must follow. configure the TSP problem, to determine the route in a minimum time; The way to implement these algorithms is by generating an initial population of individuals in which each individual represents a solution to the problem that is intended to be solved, therefore the first thing that is done is to design the chromosome of the individual as well as its fitness function that It will allow each individual in the population to be evaluated, then through a selection mechanism the best individuals are chosen who are allowed to reproduce with a very high probability between 80 and 95%, through the mechanism of crossing and mutation; the offspring obtained suffers with a very low probability alterations in the genetic code with the purpose of diversifying the offspring even more, this digital offspring continues with the next generation, repeating these mechanisms or genetic operators from generation to generation with the objective that after many generations converge to an optimal or near-optimal solution.

Tourism in Perú - Tumbes

Tumbes is located in the north of Peru, 1,260 kilometers from Lima, two hours from Máncora (Piura) (Velarde, 2017) and 30 minutes from the border with Ecuador, with 224,863 habitants, It has tourism as one of its important economic activities (National Institute of Statistics and Informatics [INEI], 2022) is a destination with a privileged location since the city connects with the main beaches, the same ones that have become famous for their white sand, turquoise sea and Caribbean climate. It is a city where we find many places rich in nature, first-class in gastronomy, with excellent beaches for the practice of adventure sports such as: paragliding, hang gliding, surfing, jet skiing, recreational fishing, diving among other sports that are practiced throughout the Tumbes coast, in general, these tourist places can be grouped into the best that the Tumbes Region has to offer. such as: Beaches, Nature, adventure, Culture and Medicinal Sites.

Today, the city is valued not only for its nature but also for the great variety of marine species that make its gastronomy look like one of the best in the world.

Tourism in Peru is also a sector that provides significant benefits and bases its development mainly on the offer of a cultural tourism product, related to archeology and history, with Machu Picchu as the main tourist icon, but incorporates other attractions; According to (Metropolitan Touring, 2024) and the Tripadvisor tourist platform, the main destinations to visit in Peru are: Lima City, Cusco City, the Machu Picchu Historical Sanctuary, Puno and Lake Titicaca, Paracas and Nazca in Ica, and the Northern Beaches; These complemented with a historical architectural offer present in the most important destination cities of the country such as Lima, which is a cultural heritage of humanity (Andina, 2023), Cusco, Arequipa, as well as Trujillo, Cajamarca and other cities that preserve a large number of vestiges. from the colonial and republican era.

The new trends in global tourism demand have influenced a diversification in the Peruvian tourism offer, in such a way that tourism development policies and planning are being oriented towards promoting other forms of tourism linked to nature and adventure, as well as such as the promotion and improvement of tourism services, connectivity infrastructure and marketing aimed at attracting new tourism source markets in the world through the work carried out by the Commission for the Promotion of Peru – (Promperú, 2022).

In relation to tourism demand in Peru, according to (Mincetur, 2024), tourist arrivals, both receptive (foreign tourists) and internal (national tourists), had an increase above what was forecast in 2022; in such a way that a total of 2,524,658 foreign tourists were registered who arrived in Peru in 2023 (+25.7% compared to the previous year), with the most important issuing countries being: Chile (23.5%), the United States (19.4%), Ecuador (9.5%), Colombia (5.8%) and Bolivia (5.3%); Likewise, countries such as Hong Kong, Taiwan, China, Korea, among others, were source markets with the highest percentage growth (+128% - '254%). Regarding internal tourism (national tourists), a significant percentage increase in arrivals was also recorded, according to (Arias, 2023), there was an increase of +28% in arrivals compared to the previous year, reaching an estimated 37 million internal transfers. at the national level. On the other hand, regarding the generation of employment through tourism, in the year 2022, from the national household survey (ENAHO), according to (ComexPerú, 2024), the following figures were obtained on the number of people employed by specific area: accommodation (66,645 Pers.), provision of food and beverages (1,244,758 Pers.), passenger transportation (790,855 Pers.), vehicle rental (2,012 Pers.), travel and related agencies (21,063 Pers.), cultural tourism activities (91,177 Pers..), sports and recreation (59,924 Pers.), tourism retail goods trade (248,762 Pers.), other specific tourist activities (133,947 Pers.) and crafts (501,715 Pers.)

Tourism in Tumbes, unlike the rest of the regions in Peru, is conditioned by an offer linked mainly to nature, taking into account that a large part of its territory is protected natural areas such as: the Cerros de Amotape National Park, the Reserve of Tumbes, the El Angolo Hunting Reserve and the Mangroves of Tumbes National Sanctuary, which according to (UNESCO, 2021) as a whole are, as of 2017, part of the "Bosques de Paz" Transfrontier Biosphere Reserve (Ecuador - Peru); In addition to having a coastline that is almost entirely made up of beaches, considered the best on the Peruvian coast. In this way, the nature tourist attractions that have a real influx of visitors in Tumbes are, among others: Punta Sal beach, Zorritos beach, Puerto Pizarro Mangroves, The Mangroves of Tumbes National Sanctuary, the Cerros de Amotape National Park; Likewise, they are cultural tourist attractions: the Cabeza de Vaca archaeological complex and the varied marine gastronomy that is offered throughout the region.

In relation to tourism demand, according to (Mincetur, 2023), through the Regional Tourism Report, it was determined through the accommodation indicator that a total of 303,000 arrived in Tumbes during 2023 with a positive variation compared to the year 2022, likewise, according to the air arrivals indicator in 2023, there was a total of 206,949 visitors also with a positive variation compared to the previous year, on the other hand, according to immigration control Tumbes a total of 204, 155 tourists entered in 2023. Regarding the origin of visitors to Tumbes during 2023, it was found that

83.7% were national visitors, with Lima (60.5%), Piura (10.6%), La Libertad (5.3%) as source markets; As for foreign tourists, they represented 6.3% of the total visitors.

3 System Design

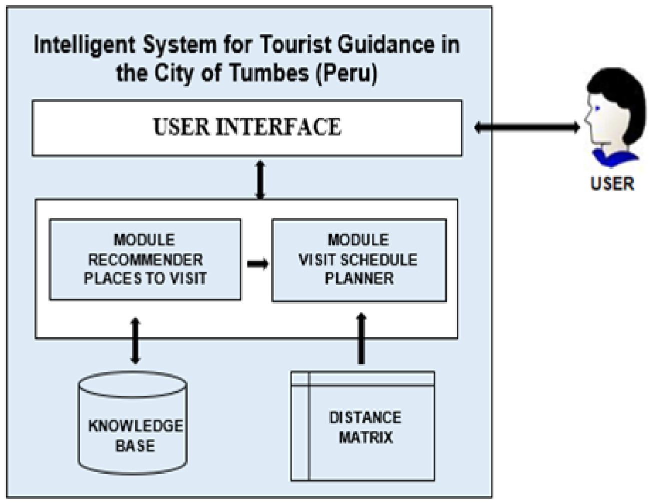

Figure 2: Functional Architecture of the Intelligent

The IS proposed in this work (See Figure 2), through the user interface receives information on the tourist's preferences, the number of days of visit, the daily schedule available for visits, and in its database it has the average time spent in each place; With this information, the first module, which is an ES, recommends the places to visit and delivers this information to the second module which, with this information, the distance matrix through a Genetic Algorithm (GA) develops the optimal route to follow, finally the IS delivers the user the visit plan. The IS has a dynamic interface that allows interaction with the user and provides detailed information about each place.

Recommend Places to Visit Module

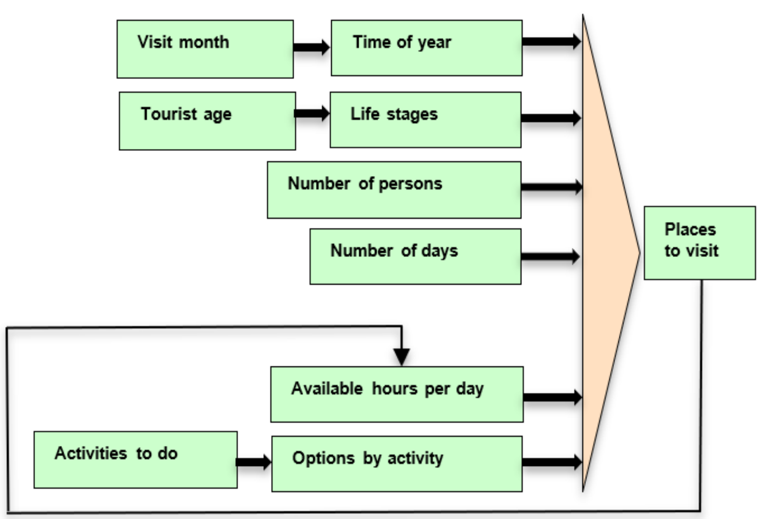

Figure 3: Recommender Places to Visit Module

This module is a rules-based ES that simulates a human expert in the tourism sector of Tumbes City. According to the tourist's preferences such as the month of the visit, age, number of people and activities to do, the ES recommends the places to visit (See Figure 3).

Knowledge Base

Information Gathering: This was done through field work, by visiting each tourist attraction on each of the five selected routes, obtaining as a result the description of the characteristics of each attraction or tourist site, including the collection of photographic material, as well as the measurement of distances, travel times, estimated time of visit to the attraction, geographic position and identification of connection points. The collaboration of tourism experts and students of said career was counted on. The data was prepared and systematized in a matrix that was then articulated to the GA.

Selection of Rules: This was done based on the knowledge of the tourism expert, taking into account essential basic factors such as: age of the tourist, time of year in which the visit is planned, number of people and type of tourist activities that they wish to carry out; in such a way that the combination of these factors allowed obtaining 285 rules, which follow the logical reasoning of a conditional proposition.

Selection of Routes: They were selected based on the knowledge of the tourism expert under the criterion that they should be routes that have the minimum conditions to be visited, since they have the basic elements to receive tourists (see figure 4) according to: a) relevant tourist sites, b) accessibility, c) tourist services; in this way five corridors or routes were selected which are: 1) beach corridor (C1: Canoas de Punta Sal - Zorritos - La Cruz - Tumbes - Zarumilla), 2) southwest dry forest corridor (C2: Zorritos - Casitas), 3) left bank corridor of the Tumbes River (C3: San Jacinto - Corrales), 4) right bank corridor of the Tumbes River (C4: Pampas de Hospital - San Juan de la Virgen - Tumbes), 5) border corridor (C5: Matapalo - Papayal - Zarumilla - Aguas Verdes).

Figure 4: Tourist Corridors in Tumbes. Adapted from Google Maps 2024

The variables that are considered in the knowledge base are shown in Table 1, 2 and Table 3.

Table 1: Variables Considered in the IS Knowledge Base

Variables	**Values**
Month of the year in which the tourist visit will take place	January, …, December
Time of the year	Rain, not rain
Tourist age (ET)	ET < 30 years, 30 years < ET <60 years, ET>60 years
Stage of life	Youth, Adults, Seniors
Number of people who will do tourism	Alone, couple, group
Tasks to do	Beaches, Nature, Adventure, Culture, Medicinal sites
Beaches	Rest, Fun, Sport
Nature	Hiking, Camping, Landscape observation, Wildlife observation
Adventure	Hiking, Canoeing, Climbing, Rock descent
Culture	Archaeological sites, Shopping and commerce
Medicinal sites	Muds, Hot springs

Table 2: Possible Places to Visit According to the Variable Activity

Tasks to do	**Places**
Beaches	El Bendito Beach, Puerto Pizarro Islands and Wetlands, La Cruz Beach, Caleta Grau Beach, Zorritos Beach, Bonanza Beach, Punta Mero Beach
Nature	Malecón and Tumbes River, Puerto Pizarro Islands and Wetlands, Crocodile Farm, The mangroves of Tumbes National Sanctuary, Puerto 25 sector, The mangroves of Tumbes National Sanctuary, El Bendito sector, Lamederos Lagoon, Natural Viewpoint and San Juan de la Virgen River, Huarapal Waterfalls, Pozo Azul Canyon, Coto Monkey Habitat, El Tigre Falls, Cerro Colorado Captain, The Port of Tumbes River Captain, Bocana Carrillo – Viewpoints, Quebrada Honda, Del Mango Canyon, El Tubo Hot Springs, Peña Blanca Waterfalls
Adventure	Huarapal Waterfalls, Pozo Azul Canyon, Salto El Tigre, The Port of Tumbes River Captain, Cerro Colorado Captain, Quebrada Honda, Del Mango Canyon, Peña Blanca Waterfalls, El Tubo Hot Springs, Natural Viewpoint and San Juan de la Virgen River.
Culture	Cabeza de Vaca Archaeological Center, Aguas Verdes Commercial Emporium
Medicinal Sites	El Tubo hot springs, Pozas Hervideros

Table 3: Estimated Time in Each Place to Visit

Places to visit (Attractions of tumbes)		Estimated visit time
1	Malecon and River Tumbes	15 MINUTES
2	Islands and Estuaries of Puerto Pizarro	4 HOURS
3	Crocodile Farm	1 HOUR
4	The mangroves of Tumbes National Sanctuary, Puerto 25 sector	4 HOURS
5	The mangroves of Tumbes National Sanctuary, El Bendito sector	4 HOURS
6	El Bendito Beach	2 HOURS
7	Aguas Verdes Commercial Emporium	3 HOURS
8	Laguna Lamederos	3 HOURS
9	Natural viewpoint and San Juan de la Virgen river	2 HOURS
10	Huarapal Waterfalls	6 HOURS
11	Pozo Azul Canyon	24 HOURS
12	Preserve Monkey Habitat	12 HOURS
13	Cabeza de Vaca Archaeological Center	2 HOURS
14	El Tigre Jump	3 HOURS
15	The Port of Tumbes River Captain	3 HOURS
16	Cerro Colorado Capitana	3 HOURS
17	Bocana Carrillo - Viewpoints	5 HOURS
18	Quebrada Honda	6 HOURS
19	Handle Canyon	6 HOURS
20	La Cruz Beach	2 HOURS
21	Caleta Grau Beach	2 HOURS
22	Zorritos Beach	2 HOURS
23	El Tubo Hot Springs	3 HOURS
24	Boiling Pools	2 HOURS
25	Bonanza Beach	3 HOURS
26	Punta Mero Beach	2 HOURS
27	Punta Sal Beach	2 HOURS
28	Peña Blanca Waterfalls	12 HOURS

Representation and Inference of Knowledge

To represent knowledge, logical rules of the IF…THEN type were used, for example:

YES Time = No Rain and Stage of life = Seniors and Number of people = Couple And Activity = Culture And Culture = Archaeological site.

THEN Place to visit = Cabeza de Vaca Archaeological Center.

The structure of the rules is stored in the knowledge base, while the values that the variables take are stored in the database.

As an inference technique, Forward Chaining was used, that is, based on facts we seek to achieve a goal. In this case, a goal is a recommendation of the place to visit, the content of which is stored in the database. Once the recommendation is found, the ES searches the database for its content to provide it to the IS.

Logical Rules

The Knowledge Base is made up of 7 submodules. Table 4 shows the number of logical rules obtained by each submodule.

Table 4: Total Rules Per Sub-module

Sub-Module	Nro. Rules
1. Month – Time	12
2. Age – Stages of life	3
3. Beaches	54
4. Nature	72
5. Adventure	72
6. Culture	36
7. Medicinal Sites	36
Total logical rules	**285**

As an example, Table 5 shows the list of rules for the tourist activity submodule “Nature”.

Table 5: Logical Rules for “Nature” Activity

Input Variables	Values	Number of Values
Travel time	Rainy, Not rainy	2
Stage of life	Youth, Adults, Seniors	3
Number of people	Family, Couple, Alone	3
Adventure	Hiking, Boating, Climbing, Rock Descent	4
Total logical rules	**2x3x3x4**	**72**

Example of some rules.

Rule 1: IF Time = Rain AND Stage of life = Young AND Number of People = group AND Activity = Adventure AND Adventure = Canoeing.

THEN Place to visit = Mango Canyon or El Puerto Río Tumbes.

Rule 2: IF Time = No Rain AND Stage of life = Young AND Number of People = Couple AND Activity = Adventure AND Adventure = Rock descent THEN Place to visit = Cerro Colorado OR Peña Blanca Waterfalls.

Visit Schedule Planner Module

This module receives the places to visit (delivered by the recommender places to visit module) According to the place of departure and the place of arrival chosen by the tourist, there can be two well-defined scenarios. In the first scenario, the place of departure and the place of arrival are the same; The second scenario is that they are different. According to (Taha, 2012), in the first scenario we are facing the classic TSP problem; and in the second in an open tour TSP, for which it is necessary to add a fictitious tourist place and treat the problem in a normal way.

Stating the problem as the TSP, the Genetic Algorithm receives the information and delivers to the IS the optimal route for the places to visit. Figure 5 shows the logic followed by the ES and GA.

To the time to stay in each place, The IS add the time to spend the night in each place and finally gives the tourist their visit plan.

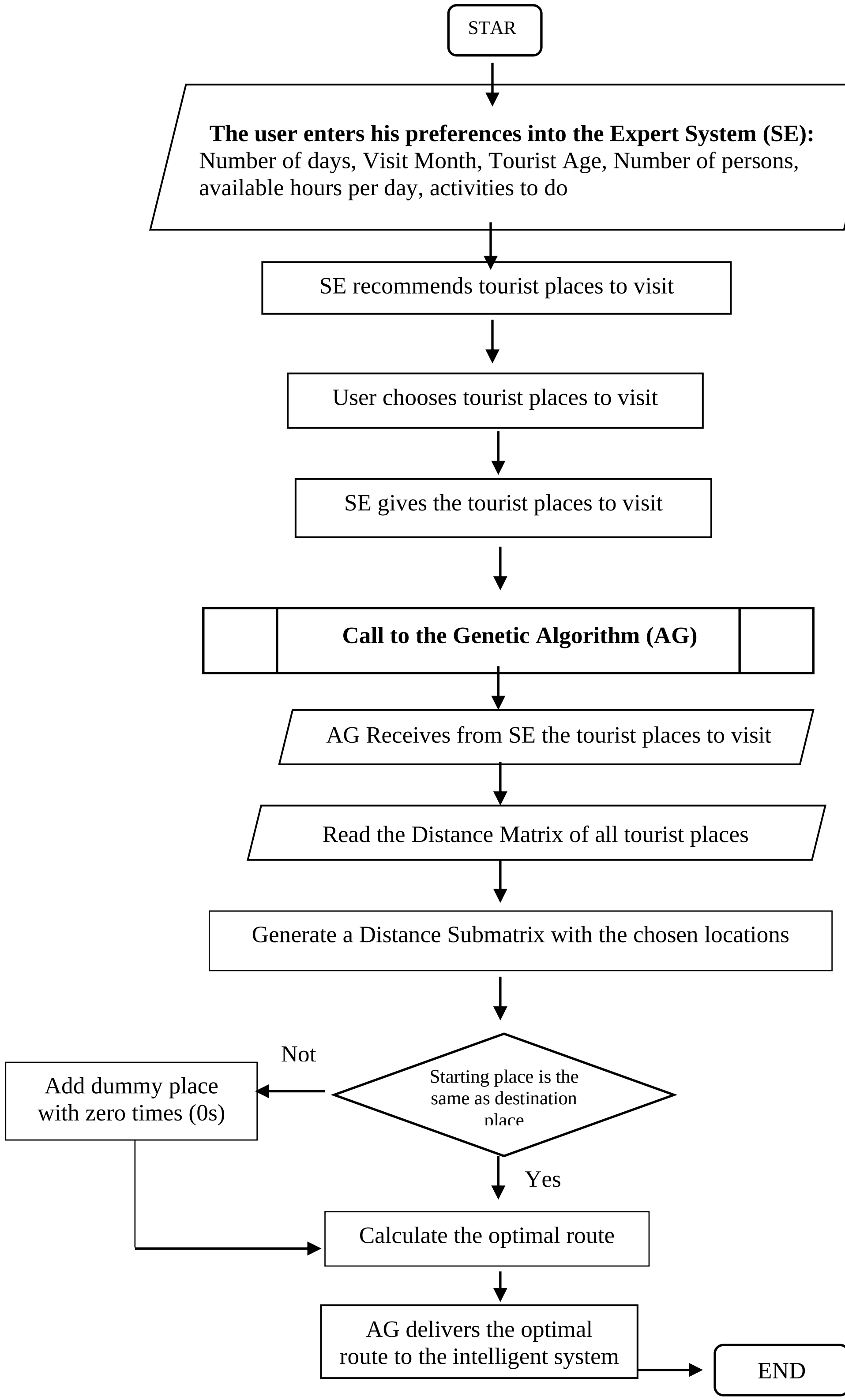

Figure 5: Flow between Expert System and Genetic Algorithm

The GA is executed by following the following steps in a special way and that is what makes it highly efficient.

1st step: From a text file the distance matrix of all tourist and non-tourist places in Tumbes is read.

2nd step: From a text file the names of the tourist places are read, including the visiting hours.

3rd step: A SubMatrix (sMatriz) of distances is built only with the places selected by the tourist.

4th step: The GA is executed and returns the sequence of places to visit and delivers them to the IS.

Genetic Algorithm (GA) Design

A program was developed in the Python programming language containing the functionality required by the GA, such as: *pop = PermMjc(nNodes): nNodes is the number of selected tourist places, this function allows generating the initial population (pop) and generates as many individuals as the size of the population (TPo).*

population = fitnees (pop, sMatriz): This function takes the previously generated population of individuals (pop) and the sub matrix (sMatriz) for the selected tourist places and calculates the quality of each individual. The function returns a population matrix that contains the same number of rows as "pop" and an additional column at the end of all the columns that contains the fitness or quality of each individual.

dist, route, HistDist = route (sMatriz, Poi_fitness): This function determines the optimal route, that is, the sequence of places to follow and the total distance in Km, the same that is contained in the variable route, the minimum distance traveled contained in the variable dist, and HistDist that contains the history of the best solution in each generation, history that is not used in the ES because it is not useful; finally comment that the sequence is expressed in number and the name of the place.

Chromosome Layout of Individuals

The chromosome of each individual was designed as a permutation of all the selected tourist places, for example if 6 tourist places were selected [25, 35, 2, 7, 9, 14] and the place of departure and arrival is the tourist place 35, Figure 6 shows a population of 5 individuals, in addition to the sub matrix that is formed from reading the entire Matrix where all the tourist places are located:

Population of 5 individuals

							Fitness
1	35	25	7	2	9	14	168.6
2	14	25	9	7	2	35	224.3
3	7	2	14	9	25	35	171.6
4	14	9	25	2	35	7	242.8
5	7	9	2	25	35	14	141.2

Distance matrix

	25	35	2	7	9	14
25	0	27.5	41.8	57	54.2	58.4
35	27.5	0	38.8	54	51.19	55.3
2	41.8	38.8	0	15.2	12.4	16.5
7	57	54	15.2	0	2.4	1.8
9	54.2	51.19	12.4	2.4	0	4.2
14	58.4	55.3	16.5	1.8	4.2	0

Figure 6: Population of Five Individuals

A characteristic of the GA is that it uses the roulette selection mechanism using a selection of 4 individuals at a time, keeping the one with the best quality, that is, the one with the shortest journey, and discarding the rest; then 2 numbers are generated randomly between 1 and the length of the chromosome, ensuring that the first number generated is the smallest than the second number generated; then a temporary population of 4 individuals is generated, the first is occupied by the best selected individual, the second, third and fourth individual is obtained by mutating the first individual through mutation by inversion, the third by mutation by exchange and the fourth using mutation by displacement, which creates a temporary population with the best individual of the four and three completely different ones, which will replace the population of the first four selected individuals; This procedure is continued until the entire population and all expected generations are finished; It should be noted that each new generation all individuals are evaluated to determine their path and the number of individuals in the population must be a multiple of 4.

Examples of the different mutations, based on the initial population, for random numbers 1 and 4 shown in Figure 7:

Population of 5 individuals

							Fitness
1	35	25	7	2	9	14	168.6
2	14	25	9	7	2	35	224.3
3	7	2	14	9	25	35	171.6
4	14	9	25	2	35	7	242.8
5	7	9	2	25	35	14	141.2

Temporary Population

0	1	2	3	4	5	
35	25	7	2	9	14	The best
35	9	2	7	25	14	Mut. by investment
35	9	7	2	25	14	Mut. by Exchange
35	7	2	9	25	14	Mut. By displacement

Individuos mutados

Figure 7: Example of the different Mutations for Random Numbers 1 and 4

At the end of the last generation, the GA reports the optimal sequence or route as a list of numbers or places and also the minimum route.

For the particular case of the example it turns out to be: [9, 25, 35, 2, 14, 7] 141.2 Km.

['00:00 EL BENDITO DETOUR', '00:00 "Y" DETOUR', '03:00 EL TIGRE JUMP', '00:00 PUERTO PIZARRO DETOUR', '00:00 BINATIONAL BRIDGE', '00: 00 LOVE FIELD DETOUR].

4 Results

The IS, given its web nature, is implemented through a robust and efficient architecture provided by a framework well known among web developers and it is Laravel under the PHP web programming language. On the server side, (Didenko, 2023) considers PHP as a very powerful language capable of performing dynamic data processing and operations.

The Intelligent System Implementation

On the other hand, the need to store user information for later retrieval has given way to the implementation of a database using the MariaDB relational database management system. This system, according to (Vaughan, 2018), is open source and effectively complies with atomicity, consistency, isolation and durability which are essential properties in relational databases. Computer Languages, Libraries and Database Management System shown in Table 6.

Table 6: Computer Languages, Libraries and Database Management System

Computer language / DBMS*	Function	Bookstores
PHP	Intelligent system logic	Dompdf 2.0
		PHPOffice 1.29
		Incorporated in Laravel 10
MariaDB	Database	
Python	Routing file (genetic algorithm)	Pandas 1.5.3
		Openpyxl 3.1.2
HTML / CSS	Graphical user interface	Bootstrap 5.3
JavaScript	User experience, dynamism and interactivity	JQuery 3.6.4

Note. SGBD* is the acronym for database management system.

According to the expert system, this was incorporated into the web system on the server side as a subsystem where the rules were transformed into lines of PHP code so that the web application server could interpret them and provide the correct information to the client. according to the decisions you make during your interaction with the graphical interface in the browser of your choice.

Regarding the genetic algorithm implementation, it was carried out using the Python programming language. According to (Gagnon, 2021), this language is general purpose, however, its potential lies in analyzing and processing data and performing calculations efficiently and is useful for the development of desktop applications and websites. With this, PHP-Python integration occurs on the server side.

Finally, on the client side, the graphical user interface was designed using HTML and CSS. Knight, (2022) states that these design languages and web styles define the format and style for the presentation of information on online sites. However, to give it a touch of interactivity, the JavaScript programming language was used, a script-based language known for giving graphical user interfaces interactivity and dynamism.

For the intelligent system implementation, the Rational Unified Process (RUP) software development methodology was used, which provided a systematic and structured approach during the life cycle. For (Coutinho, 2021), this methodology allows us to build quality software and the documentation is based entirely on the unified modeling language (UML).

The RUP methodology is made up of 4 phases that were executed during the development of the system. The first phase is initiation and in this the system requirements were analyzed and the scope and objective were defined. The next phase is elaboration and in this representative designs of the requirements were made in UML diagrams such as the one shown in Figure 5. Then, in the construction phase, key components of the system were implemented. Finally, in the transition phase, the final implementation was carried out, that is, the incorporation of all the key components implemented and tested. Subsequently, validation processes were carried out in the following section of system development. System Deployment Diagram shown in Figure 8.

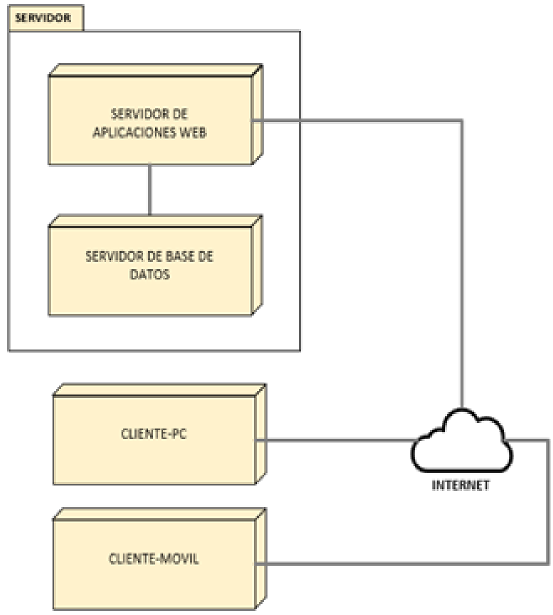

Figure 8: System Deployment Diagram

The graphical interface of the IS is presented below. On the home screen (See Figure 9) there are three options: Plan to your liking, consult tour operators and organize your plan with the smart assistant. In the first two options, it is the tourist who makes the decisions without any help, so we will focus on explaining the user interface when it requires the IS to help him organize his trip.

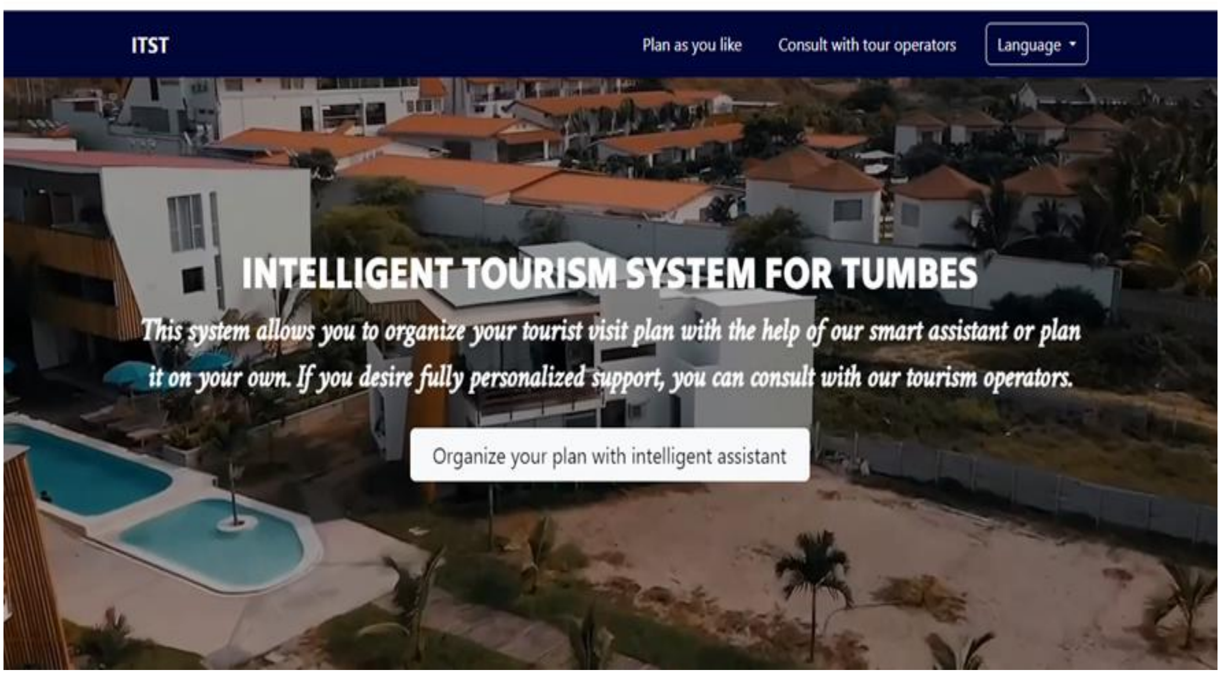

Figure 9: Intelligent System Home Page

Figure 10 corresponds to the form page provided by the intelligent assistant with the objective of collecting initial data.

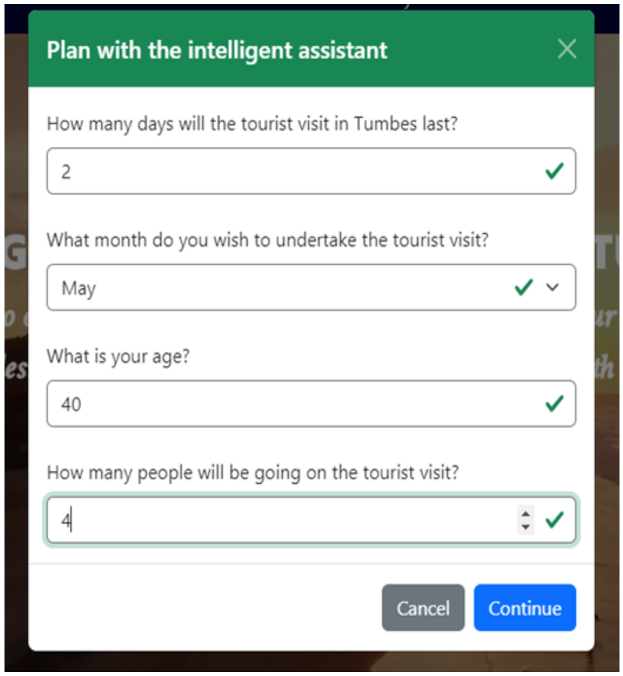

Figure 10: Form Page Provided by the Smart Assistant

After filling out the form and clicking on the next button, the page for the selection of tourist attractions appears (See Figures 11 and 12), when the user chooses the activities to be carried out, the places that can be chosen appear on the map, if the user chooses a place there is the option to see the name, average time of visit, as well as access its image gallery, If the user clicks on the Add the place button, it is incorporated into his/her visit plan. Also, there is the "icon details" button that provides a legend to differentiate the icons of the places and the Next button to click when all the tourist attractions you want to visit have been added.

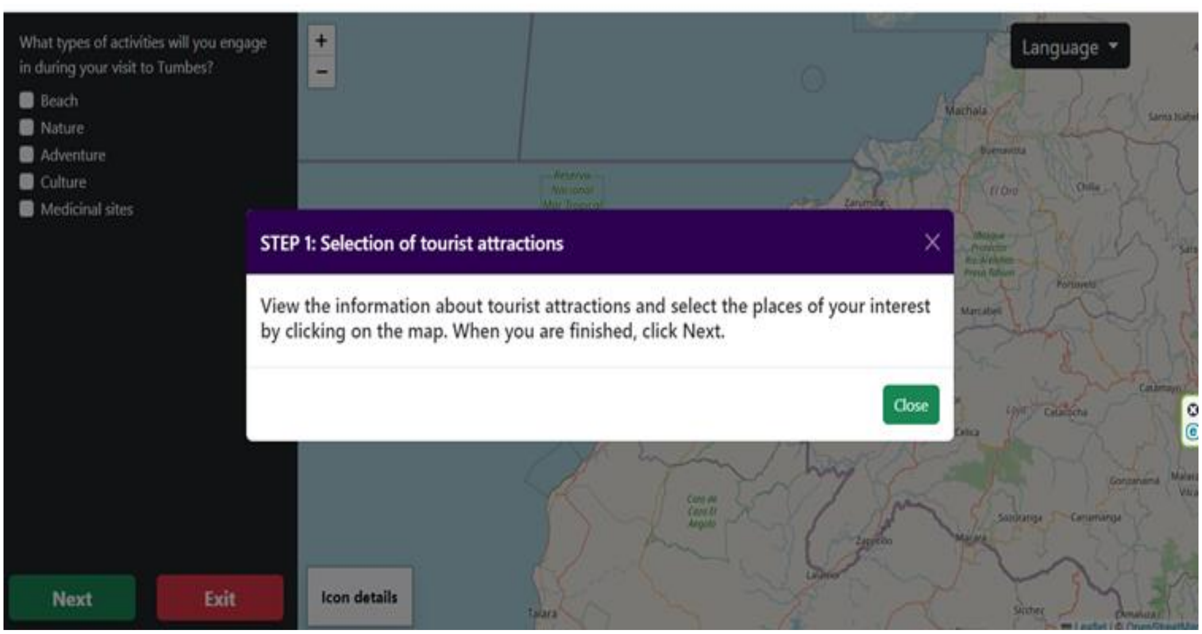

Figure 11: Tourist Attraction Selection Page with Instructional Message

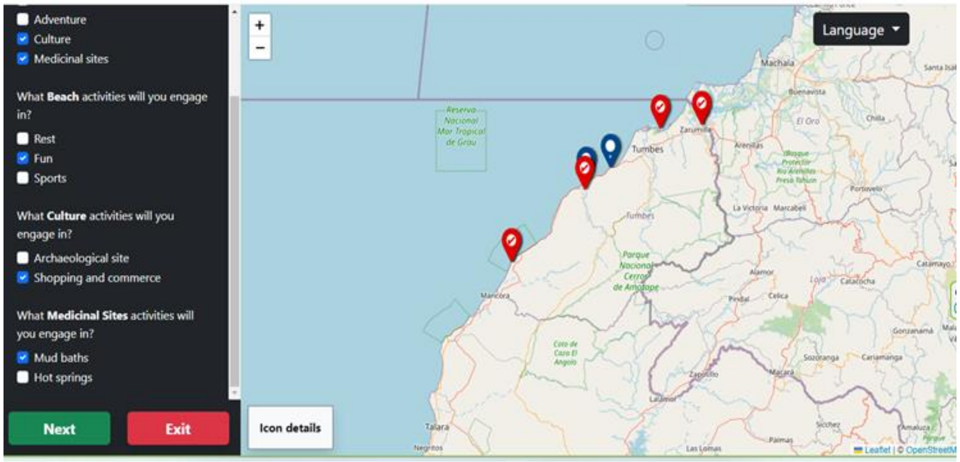

Figure 12: Page for Selecting Tourist Attractions with the Activities to Do

Figure 13 shows a message indicating the steps to follow, then Figure 14 shows the interface for selecting the start and end points of the tourist tour, in addition, in Figure 15 you can adjust the start and end times per day, however, the end time can be modified during the generation of the tourist visit plan.

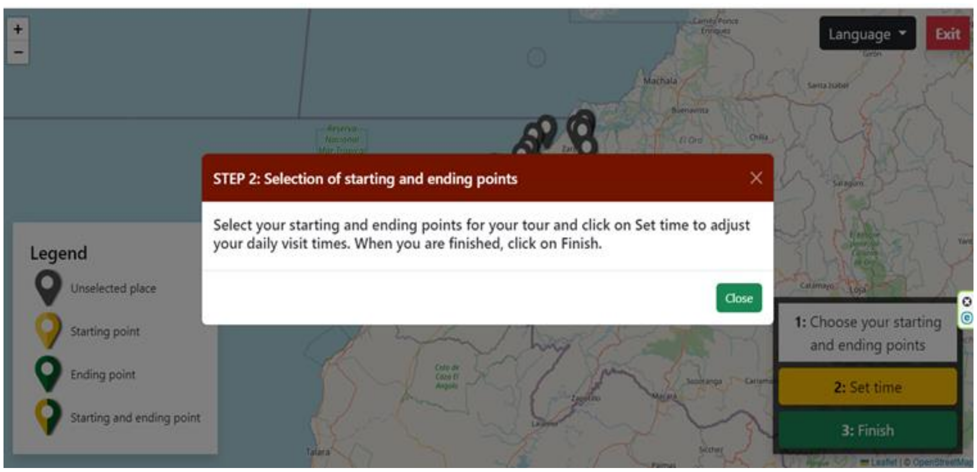

Figure 13: Page with Instructional Message for Selecting the Start and End Point of the Tour

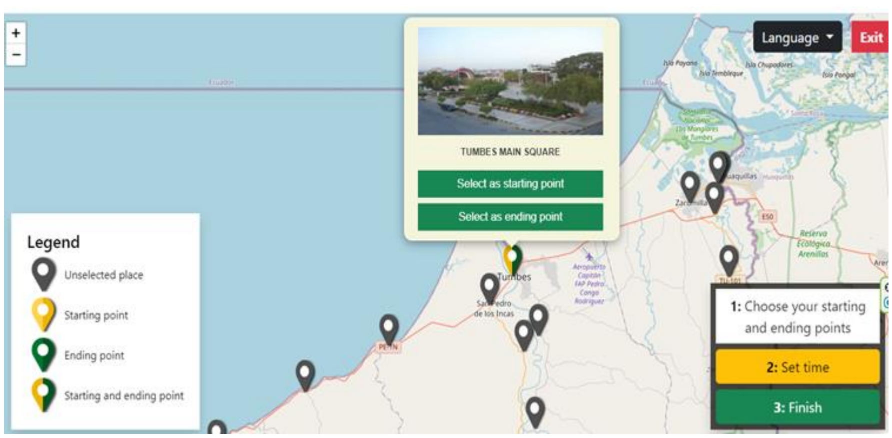

Figure 14: In this Section You Can Choose and Review Photos and Descriptions of Each Place

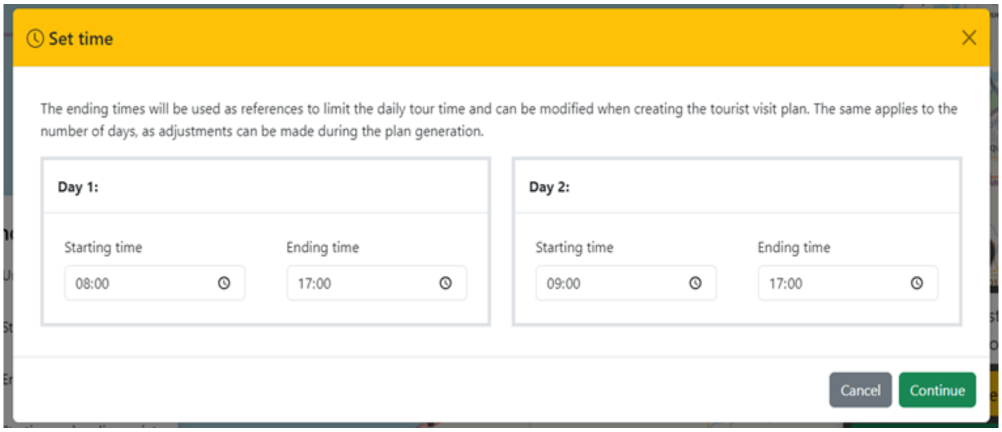

Figure 15: In this Section You Can Choose the Start and End Time of Each Day

Once you have finished selecting the start and end points, click on the Finish button to begin building the tourist visit plan. Figure 13 shows the plan already generated with the information that has been added during the interaction with the intelligent system.

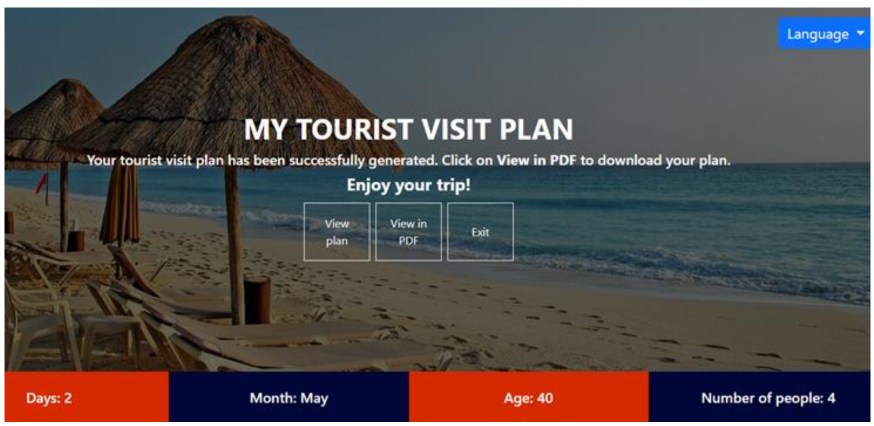

Figure 16: Page of the Generated Tourist Visit Plan

Finally, the plan has been generated and the option is presented to view it in PDF or to Exit, which implies deleting this plan from the system. Likewise, data such as the number of days, month, age and number of people that were entered in the intelligent assistant form are also seen. An example of a plan that generates the IS can be seen in Figure 16 and 17.

System Operation Case

A user wants to make a tourist visit in Tumbes and accessed the intelligent system to plan his itinerary. This user has never traveled to said place so he opted for the option of organizing his plan using a smart assistant. The assistant presented you with a form to enter certain personal data and select categories and activities (Figure 10). The data entered is:

- How many days will you make the tourist visit in Tumbes? Answer: 2.
- In what month do you want to make the tourist visit? Answer: July.
- How old are you? Answer: 29.
- How many people will make the tourist visit? Answer: 2.

Subsequently, the user selects the following categories of activities: Beach, Nature, Adventure and Medicinal Sites. From each category, selected the following activities:

- **Beach:** Selected Rest and Fun.
- **Nature:** Selected Hiking, Camping and Landscape Observation.
- **Adventure:** Selected Hiking and Canoeing.
- **Medicinal Sites:** Selected only Hot Springs.

After completing the form, you clicked the Next button and were directed to the page to select the tourist places you want to visit from among all those that the assistant recommended according to the information entered in the form (Figure 11). The System recommends several places.

Of all these recommended places, the user added the following places to his sightseeing plan:

- Bonanza Beach
- El Tubo Hot Springs
- Caleta Grau Beach
- Bocana Carrillo – Viewpoints
- Malecon and River Tumbes
- Islands and Estuaries of Puerto Pizarro
- The Mangroves of Tumbes National Sanctuary Sector Puerto 25

After adding these locations to your plan, you clicked Next and were directed to the page to select your start and end point for the sightseeing tour (Figure 12). On the current page, the user selects the Plaza Mayor of Tumbes as the starting and ending place because he does not know the other places to stay until he finishes his tourist visit. Likewise, configure the time by setting for the first day your departure at 10 AM and arrival at most until 6 PM, in the same way you configured for the second day with the same departure and return times. After carrying out all these actions, you click Finish and after a few seconds, your tourist visit plan generated by the intelligent system is presented (Figure 14) with the option to view it in PDF format.

Figure 17: Detail of the User's Visit Plan

The results indicate that the GA provides optimal solutions for problem sizes of 12, 24 and 36 tourist places to visit with a running time of 5.6 seconds, that is, 0 errors; in addition, for problems of 48 places it also delivers optimal solutions with 0 errors in a time of 15.8 seconds, likewise for 61 tourist places to visit, the GA finds highly satisfactory solutions with a coefficient of variability of 0.0738% in a running time of 54.3 seconds; which means that the GA is very precise in its answers.

5 System Validation

This validation aims to verify whether the logical rules of the Expert System match the answers given by a human expert (tourism expert in the city of Tumbes).

Expert System Validation

The method to validate the Expert System is against the expert, that is, a set of rules were randomly chosen that, in the form of questions, must be answered by an expert different from the expert or experts who provided the knowledge. The ES will answer the same rules, and the percentage of coincidences will be measured.

Of the total number of rules, which are 285, 15 rules were chosen at random, the ES and the human expert agreed on 12 responses and disagreed on 3.

Under the hypothesis that the ES and the human expert coincide in their answers by 80%, the Wald-Wolfowitz nonparametric statistical test was used for the confidence test, the following result was obtained:

$$-1.96 < Zexp = 1.57 < 1.96$$

It is observed that the statistic $Zexp$ =1.57 falls in the acceptance interval of the hypothesis, so it is concluded that:

The ES will allow you to make recommendations about the tourist places to visit, as if you were a tourist expert with a confidence of 80%.

Routing Validation

The validation of Vehicle Routing, when a metaheuristic such as Genetic Algorithms is used, implies knowing the computational complexity it faces, which is why we show the mathematical model of a small instance of a TSP problem with 6 nodes or places, and through mathematical induction we show the complexity through Table 7, which is shown.

Table 7: System Complexity

	1	2	3	4	5	6
1	0	61	65	69	50	61
2	69	0	56	57	70	56
3	63	62	0	48	37	45
4	61	56	50	0	48	48
5	68	68	50	20	0	48
6	51	52	50	30	40	0

Non-symmetric matrix

$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	$x_{1,4}$	$x_{1,5}$	$x_{1,6}$
$x_{,2,1}$	$x_{2,2}$	$x_{2,3}$	$x_{2,4}$	$x_{2,5}$	$x_{2,6}$
$x_{3,1}$	$x_{3,2}$	$x_{3,3}$	$x_{3,4}$	$x_{3,5}$	$x_{3,6}$
$x_{4,1}$	$x_{4,2}$	$x_{4,3}$	$x_{4,4}$	$x_{4,5}$	$x_{4,6}$
$x_{5,1}$	$x_{5,2}$	$x_{5,3}$	$x_{5,4}$	$x_{5,5}$	$x_{5,6}$
$x_{6,1}$	$x_{6,2}$	$x_{6,3}$	$x_{6,4}$	$x_{6,5}$	$x_{6,6}$

Decision variables

Mathematical Model

$$MinRt = \sum_{i=1}^{n}\sum_{j=1}^{n} t_{i,j}x_{i,j}$$

$$s.a$$

$$\sum_{j=1}^{n} x_{i,j} = 1; \qquad i = 1,2,\cdots,n$$

$$\sum_{i=1}^{n} x_{i,j} = 1; \qquad j = 1,2,\cdots,n$$

$$u_i - u_j + nx_{i,j} \leq n-1; \qquad 2 \leq i \neq j \leq n$$

$$x_{i,j} = (0,1);\ u_i(entero)$$

Table 8: Mathematical Induction to Show the Complexity of the TSP

"n" represents the number of nodes or places to visit	***n***	Variables	Restricciones
	6	41	32
N° of variables = *n* x *n* + *n* -1 = 6 x 6 + 5 = 41	7	55	45
N° of restrictions: *n* + *n* + 2[(*n* x *n*) / 2 – (*n* + 2)	8	71	60
N° of restrictions: 6 + 6 + 2[(6 x 6) / 2 – (6+2)	9	89	77
N° of restrictions: 12 + 2[18 – 8]	⋮	⋮	⋮
N° of restrictions: 12 + 2(10)	50	2549	2496
N° of restrictions: 32	61	3781	3717
	1000	1000999	999996

Mathematical Induction to Show the Complexity of the TSP shown in Table 8. Knowing that the problem exploits both the number of variables n^2+n -1, and the number of restrictions n^2 - 4, in quadratic form it is necessary to validate the GA to be sure of the results of the algorithm therefore; validating the GA is to guarantee the stability of the vehicle routing algorithm that assists the tourism expert system, with the optimal route that the tourist must take after choosing their preferred places is determined through a variance analysis using equation (1,2), in order to establish if there are significant differences in the results. In this equation, the parameter yijn represents the response of the genetic algorithm expressed in terms of the minimum route of the selected places in hours; Ai, is the effect caused by the i-th factor A (Number of generations 1000, 2000 and 3000) and Bj is the effect caused by the j-th factor B (population size 100, 200 and 300); (AB)ijn represents the effect caused by the interaction of the two factors and n repetitions; eijn, represents the error caused by the i-th factor A, j-th factor B, in replica n. For the genetic algorithm, the information collected must meet the required independence and normality requirements. The analysis of variance is carried out under a confidence interval of 95% and 99%.

$$y_{ijn} = \mu + A_i + B_j + (AB)_{ijn} + e_{ijn} \qquad (1)$$

$$i = 1,2,3,4;\ j = 1,2,3,4;\ n = 1,2,3,4 \qquad (2)$$

Tests were made for different network sizes, especially for the choice of 12, 24, 36, 48, 61 places as the problem size because they are within the maximum range of all the places to visit; for each size, the places were randomly selected and five different samples of each size were obtained, to which the factorial design mentioned in equation (1) was applied. The results are shown in Table 9:

Table 9: Behavior of the Genetic Algorithm, for different Number of Places

N° of places	**Robustness of the A.G.**	**Parameters**
12, 24, 36	Always delivers optimal solutions	TPo = 100; NG = 1000
		Tiempo de ejecución: 5.6 seg.
48	Always delivers optimal solutions	TPo = 200; NG = 1500
		Tiempo de ejecución:15.8 seg.
61	Delivers highly satisfactory solutions with a coefficient of variability of 0.0738%	TPo = 300; NG = 3000
		Execution time: 54.3”

In Table 9, you can see the analysis of variance for the case of 61 locations, finding that factor A is highly significant in solving the problem, however factor B nor the AxB interactions show significance, and refining the analysis a little more using Duncan's tables, it can be seen that the optimal parameter of factor A is 3000 generations, with respect to factor B all levels behave statistically the same, however numerically the level of 300 individuals has a better performance, which is why it is selected as optimal parameters; With these parameters, the algorithm was executed with 5 different test instances, finding that the algorithm is highly reliable considering that the root mean square error is of the order of 0.11 km, see Table 10. Finally, an extensive analysis of the GA, with the examples of the repository according to reports (Jaradat & Diabat, 2019), our results are better than those provided by all the other authors who delivered their solution; however, comparing them with the optimal solution of which it is not known how they obtained them; our algorithm has a high efficiency in finding solutions. Behavior of the GA with the Selected Parameters for 61 Locations shown in Table 11.

Table 10: Analysis of Variance for the Case of 61 Cities

ANVA					
SOURCE OF VARIATION	GL	SC	CM	Fc	SIG
TREATMENTS	8	4000.9856			
A	2	3929.8506	1964.925	25.5533	**
B	2	41.827222	20.91361	0.2720	
AxB	4	29.3078	7.326944	0.0953	
ERROR	27	2076.1700	76.89519		
TOTAL	35	6077.1556			
	CV =	11.9851%			

Table 11: Behavior of the GA with the Selected Parameters for 61 Locations

Repetition	Instance 1 (Ref)	Instance 2	Instance 3	Instance 4	Instance 5
1	632.9	3234.66	3201.41	3216.51	3259.31
2	632.9	3216.32	3178.34	3240.73	3241.20
3	632.9	3261.13	3247.03	3248.75	3241.24
4	633.1	3234.47	3219.11	3255.92	3250.50
5	633.1	3207.78	3225.86	3237.14	3235.81
6	633.2	3255.39	3194.51	3237.82	3240.88
7	632.9	3227.74	3176.45	3211.44	3222.45
8	632.9	3267.58	3186.58	3240.82	3225.15
9	632.9	3256.12	3234.79	3248.39	3252.58
10	632.9	3236.73	3237.44	3195.75	3284.68
Promedio	632.97	3239.792	3210.152	3233.327	3245.38
Maximum	633.2	3267.58	3247.03	3255.92	3284.68
Minimum	632.9	3207.78	3176.45	3195.75	3222.45
RMSE	0.11	18.77	24.62	18.15	17.02
Deviation from the mean	0.0174%	0.579%	0.7671%	0.5614%	0.5246%

6 Discussion

An extensive analysis of the GA, with examples according to reports (Jaradat & Diabat, 2019), indicate that our results are better than those provided by all the authors, however, comparing them with the optimal solution they obtained using the Firefly algorithm (FA) with the k-means clustering technique, our GA has high efficiency in finding solutions with lower computational cost and shorter response time.

Similarly, unlike the work of (Fernandez et al., 2022), which proposes a ES based on logical rules for tourism in a province of the City of Cajamarca, we propose an intelligent system, which in addition to the logical rules module (ES), is complemented with a genetic algorithm based on the vehicle routing method to obtain optimal visit routes taking into account the preferences of the tourist.

However, we agree with the work of (Baldeón et al., 2023) when it is indicated that, to promote tourism, which is currently called scientific tourism, a marketing plan must be promoted or carried out taking advantage of technologies, social networks and cloud computing as an important ally to offer the visitor a tourist experience that is in line with their preferences.

Along the same lines, we partially agree with one of the objectives of the work of who proposes a mobile application that improves the tourist flow in the city of Trujillo, using a questionnaire, checklist and record of visits, which were validated by expert judgment.

Likewise, we partially agree with the work of in the sense that they obtained a repository of tourist information and implemented a web expert system that allows information to be consulted from anywhere in the world, supporting tourists when planning a visit. We did field work in each tourist location and were able to capture the tourist information in information sheets that are available in the IS, promoting tourism in the Tumbes Region by providing tourists with an optimal visit itinerary based on their preferences and, as a strength, the system is accessible from laptops and mobile devices, making it easy to use.

7 Conclusions

An innovative Intelligent System was developed to guide tourists who wish to visit the city of Tumbes. The system uses rule-based Expert Systems and a Genetic Algorithm, two Artificial Intelligence techniques that complement each other to obtain an optimal visit route considering the tourist's preferences.

The entire Tumbes region was covered and tourist, geographic, georeferenced information and photographs of 28 tourist places were consolidated, which were selected under the professional criteria of tourism experts and with the advice of experts in Artificial Intelligence, the knowledge base was developed, the distance matrix was created that relates the 28 tourist places and the 33 connection points, information that is used by the ES and the GA.

The IS manages to obtain the visit plans to the Tumbes region, through the intelligent assistant option, after entering the tourist's preferences.

Human experts in tourism other than those who developed the knowledge base validated the Expert System, obtaining a confidence level of 80%.

It is demonstrated that by combining Artificial Intelligence techniques, Intelligent Systems can be developed with better performance than using only one of them, and new versions can be worked on that involve cost data for food and lodging services in each place in real time.

It was possible to integrate computational languages, libraries and database managers to implement the subsystems and obtain an Intelligent System that works on the web. The IS will serve to promote tourism in the city of Tumbes and can be installed in public and private institutions related to tourism.

The Intelligent System can be adapted to be used in tourist orientation in other cities.

8 Future Work

Consider other tourist preference options in the system, such as, for example, real-time information and costs of accommodation services, food costs and entry costs to each tourist site, etc.

Connect the system in real time with the places to visit, to find out if the place is available to be visited, if there are available spaces, etc.

Integrate the system with the tourist information systems of local, regional and national governments.

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Authors Biography

Raúl A. Sanchez-Ancajima, Obtained the degree of Licenciado in Mathematics from the Faculty of Sciences of the National University of Piura, Peru (2004). He obtained a Master's degree in science with a major in Applied Mathematics from the National University of Piura, Peru (2011). In 2021 I obtained a PhD in Mathematics from the National University of Trujillo, Peru (2021), with an internship at USP in Brazil. Senior Lecturer at the National University of Tumbes, Peru. My research interests are focused on Artificial Intelligence, Optimization Methods and Fractional Calculus.

Miguel Jimenez-Carrion, Doctor in Industrial Engineering from the National University of Piura, Peru, 2013. He was the winner of a mentoring contest to advise a participant with her thesis in Economic Engineering at the National University of the Altiplano of Peru. He is currently a Full Professor of the Operations Research Department of the Faculty of Industrial Engineering, and a RENACYT researcher; External Evaluator for CONCYTEC and Innovate Perú. His research interests include artificial neural networks, genetic algorithms, fuzzy logic, fuzzy controllers, shape recognition, mathematical modeling, and optimization.

Flabio Gutierrez, obtained my Bachelor's degree in Mathematics in 1991 at the National University of Trujillo (Peru), a Master's degree in Computer Science in 1997 at the University of Cantabria (Spain), I did doctoral studies in computer science at the Polytechnic University of Valencia (Spain) in 2013. In 2017 I obtained a PhD in Mathematics from the National University of Trujillo (Peru). I am currently a professor in the Department of Mathematics at the National University of Piura (Peru). My research area is artificial intelligence.

Adriel O. Hermenegildo Alfaro, He graduated with a degree in Tourism from the Faculty of Social Sciences of the National University of Trujillo, Peru (2001). He obtained the degree of Magister Scientiae in Ecotourism at the Universidad Nacional Agraria La Molina, Peru (2022). Associate Professor at the National University of Tumbes (UNTUMBES), Peru. His lines of research are focused on Tourism, Ecotourism, Adventure Tourism and Tourism Operation.

Edwar Lujan-Segura, I obtained the title of computer engineer in 2014 from the National University of Trujillo. He also obtained a master's degree in 2017. I am currently a doctoral candidate at the National University of Trujillo. My research areas are: Artificial intelligence, combinatorial optimization, among others.

Jordan A. García Blas, received a Bachelor's degree in Computer Science from the Faculty of Physical and Mathematical Sciences of the National University of Trujillo in 2022. My research interests are artificial intelligence, optimization methods, and web application development.