Capstone Final Project

[191018] An Agent-Based Approach for Tourist Planning

Geraldine Beltrán Pérez [a,c], Daniel Guillermo Rodriguez [a,c]
Gabriel Zambrano Rey [b,c], Jose Fernando Jimenez Gordillo[b,c]

[a]*Industrial Engineering Student*
[b]*Associate Professor, Project Director, Department of Industrial Engineering*
[c]*Pontificia Universidad Javeriana, Bogotá, Colombia*

Abstract

Tourism behaves as a dynamic evolving complex system, encompassing numerous factors and activities that are interdependent and whose relationships might be highly nonlinear (Baggio, 2008). Recommendation systems and route planners are frequently used to filter information that is not important and in turn offer a personalized service for tourists (Noguera et. al 2012). In this context, Agent-Based Models (ABM) are an appropriate tool for decision making because they allow representing complex systems or situations with autonomous agents in an established scenario (Nicholls et. al, 2017). In addition, ABM has an ability for modeling emergent phenomena, thus phenomena such as cultural norms that come up into society because of interactions between individuals and other agents, sometimes even in a counterintuitive manner, and that are not well captured by traditional modeling techniques (Nicholls et. al, 2017). In this perspective, this project proposes an ABM to simulate tourism in Bogota. The main objetictive is to support the tourist in the planning and realization of different tourism activities, considering qualitative and quantitative variables that maximize the experience of a tourist visiting Bogota (Colombia), which in turn may contribute to the development of this economic sector.

In general, the results in several scenarios are positive according to the average level of satisfaction obtained, which means that the recommendations generated by the application are adequate. Therefore, the model has the potential to help current tourism platforms to better accomplish satisfactory recommendations for tourists and even be the basis for the development of a new app, so this would allow promoting the growth of tourism in La Candelaria, Bogota.

Keywords: Agent Based-Modeling, Multi-Agent System, Netlogo, Potential Fields, Recommender systems, Tourism.

1. Introduction and problem statement

Over decades, tourism has experienced continuos growth and deepening diversification becoming one of the fastest growing economic sectors worldwide. Modern tourism is closely linked to country's development, encompassing a growing number of new destinations. These dynamics have turned tourism into a key driver for socio-economic progress, for instance, international tourist arrivals grew by 7 % in

2017 reaching 1,32 billion (World Tourism Organization, 2018). Therefore, tourism plays a significant role for the gross domestic product, creating additional jobs and providing employment for the population, and enhancing the foreign trade balance (Cámara de turismo de la provincia de Mendoza, 2017).According to Colombia's Minister of Commerce, which oversees tourism investment, Colombia experienced in 2019 an increase of 6,91% compared to the same period in 2018, or 14,6 million visitors during the first six months of 2019 compared with 23,3 million during the entire 2018 (Migración Colombia, 2019).

It is important to note that the situation of tourism in Colombia has been positively affected by the end of the armed conflict; thus, the new conditions have made all the destinations in Colombia a realistic alternative for tourists (Dinero, 2018).

For instance, Bogota - Colombia's capital - received in 2017 more than 2,000 million dollars in tourism's sector according to the District Tourism Institute, (Conexión capital, 2018). Besides, Bogota received recognition from Centro de Pensamiento Turístico de Colombia (Centro de pensamiento turístico-Colombia, 2018), after the city occupied the first place in the measurement of the Regional Tourism Competitiveness Index of Colombia in 2017, for the second consecutive year. In this way, the work and commitment of the District to enhance tourism development with high levels of efficiency and focus on sustainability is highlighted.

Nevertheless, in various forums organized by unions and government agencies responsible for making tourism in Colombia a competitive industry, they have noted among other weaknesses, the lack of timely information regarding the characterization of the regional offer (SITUR, 2018). In addition, there are serious deficiencies for the services provision, especially for foreign tourists, such as the lack of bilingual staff, as well as adequate and timely figures to evaluate strategies and instruments for destination promotion (Vanguardia, 2016). The aforementioned aspects cause delays innovation and it does not encourage the arrival of new investors, and on the other hand, the lack of timely information produces a negative image in front of foreigners.

Moreover, the tourism system consists of a large number and variety of actors who interact with each other within a series of natural and socioeconomic systems at different spatial and temporal scales. Actors of a given tourism system can range from individuals (tourists, tourism operators, local residents) to institutions (destination, national and regional governments, and policy-makers, tourism lobby groups); from private sector (airlines, hotels) and non-governmental groups (conservation organizations, hotel and tourism associations) to public sector (local, national, regional and international government bodies); and from local (one-off restaurants) to international (hotel chains). The variety of actors and their various levels of interactions contribute to the complexity of the tourism system (Johnson et. al, 2016). Therefore, the tourism system has a behavior extremely changing, dynamic and sometimes even turbulent. As Russell & Faulkner (1999) suggest, tourism can be understood as an open, living system based on the chaos–complexity approach, in which nonlinear relationships an instability prevail, and individual differences and externalities drive adaptive responses in a dynamic, self-organizing, and emergent manner.

Agent-based modeling (ABM) has the ability to capture heterogeneous behavior and motivations, as well as the complex, changing, and sometimes for competing relationships between multiple and diverse social agents. Moreover, agents can remember their current and previous states and can also be programmed to learn about the environment and about the status of other agents using artificial neural networks or evolutionary algorithms such as the genetic algorithm (Nicholls et. al, 2017). This enhanced level of realism is critical to ABM's potential as a real-world decision support system in that users who can understand and relate to a model of reality are more likely to engage with it and make use of its outcomes (Abdou et. al, 2012). Therefore, ABM has several advantages to model tourist systems, and decision making.

On the other hand, during the last decade, the emergence of new technologies has led to the development of smart cities: an instrumented, interconnected and intelligent city which analyzes and integrates critical information of functioning cities, fostering sustainable economic development (Praharaj et al, 2019). In order to provide technology-based solutions that are effective and efficient. In addition to improving the results that are relate to the people, systems and processes of companies, government and other public and private sector entities, the main objective of smart cities is to improve the quality of life of inhabitants. Consequently, smart tourism has emerged in recent years as a subset of the smart city concept, with the aim of providing tourists with solutions that address specific travel-related needs (Khan et al, 2017).

Considering that the use of technology as a tool that facilitates access to information is a reality, and that as time passes, the implementation of the smart city concept is more likely; this work presents an ABM aimed to support the tourist, within the scenario of a smart city, focused on the organization and realization of different tourist activities. The objective of this work is twofold: first, proposed a distributed approach for a tourist recommendation, and second, implement such approach and simulate various scenarios to validate the recommendations given. The proposed model was designed based on several parameters, as for instance, tourist preferences, the set of interest's points, their current status, trips start and finish dates, among others. Besides, the main purpose of using ABM was to draw up a customized daily activity plan and the route, for each tourist to follow, on a rolling horizon basis, capturing the distributed escence of the current dynamics (tourist behavior). For assisting the tourist, real-time information, like how overcrowded is an activity, and events close to tourist's location, among other data, are used for maximizing the tourist's experience (based on the smart city concept, which defines such data availability).

2. Research question and objectives

Considering the global markets, the idea of Smart Cities, the current and projected infrastructure in Colombia and the relevance of the tourism industry for the country, this project looks for answering the following research questions *how can an Agent-Based application help tourist to better plan their itineraries? What kind of information must be considered to offer the best activity plan?* Therefore, the main objective is ***to design and implement an ABM that plans tourist routes aiming to improve the tourist's experience, within the Colombian context***. This main objective was achieved by accomplishing the following specific objectives:

- Analyze the different Agent-Based paradigms and choose the most suitable one for the tourist planning problem
- Design an Agent-Based Model for the tourist planning problem
- Implement the proposed Agent-Based Model using an Agent-Based simulation software
- Validate, through various scenarios, the design approach and report results based on performance indicators for a specific case study.

2.1 Design requirements

The proposed model must accomplish the following requirements:

- The model must consider quantitative and qualitative variables.
- The model must be able to adapt to different scenarios.
- The model must be able to generate a proper route for the plan of activities.
- The model must consider the available hours for the activities recommended.
- The model must consult the opinions of tourists that had visited this activity.
- The simulation environment must generate a performance indicator for the solution of each scenario.

2.2 Design constraints

The proposed model must consider the following constraints:

- The design of scenarios depends on the information available. So, if the information is limited, the scenarios will be based on theoretical information.
- The model will be a simulation implemented in NetLogo; therefore, the scope of the simulation model is to proof the proposed concept.
- The simulation will be developing with information gathered from different websites. However, the information gathering is done asynchronously (offline). The actual platform, with communication protocols to fetch up-to-date information are out of scope of this project.

2.3 Norms and standards

The methodology that will be used in this project is described by the ISO 13053-1 for the quantitative methods in process improvement. This methodology typically comprises five phases: Define, Measure, Analyze, Improve and Control ("ISO 13053-1, Quantitative methods in process improvement — Six Sigma — Part 1: DMAIC methodology," 2011).

3. Literature Review

There is a plethora of expert and intelligent system corresponding to tourism, either (3.1) Route planning, (3.2) Activity recommender systems and (3.3) Hybrid recommender systems. This section gathers a few documents about how the Agent-Based simulation (ABM) has been used as an important tool for the development of services related to tourism.

3.1 Route planning

There are many experts and intelligent systems aimed at obtaining the best routes. For instance, Garcia Magariño (2015) present an Agent-Based Simulation (ABS), called ABSTUR. In this platform, experts can load a set of routes from a file, simulate the tourist behaviors in the set route with several parameters, observe whether there is any route overcrowded or non-profitable according to the people signed up for each route in the simulation. On the other hand, Mcardle et. al (2014) introduce a micro-simulation of urban traffic flows with a large-scale scenario for the Greater Dublin region in Ireland. They introduced this simulation in order to drive individuals' decisions on trip destinations within an assigned daily activity plan. Each person in the population is represented by an agent that can make decisions and manage daily activities to the greatest personal return. Table 1 reports the literature review about route planning, the criteria considered, and the methods used.

Table 1 Route planning methodologies.

Title	Author	Criteria	Tools
Sistema de ayuda al turista Modelo para la planificación de un viaje personalizado.	Beatriz Rodríguez Díaz*, Rafael Caballero Fernández (2012).	• The decision maker. • Set of alternatives • The attributes • The objectives	Metaheuristic.
A real-time personalized route recommendation system for self-drive tourists based on vehicle to vehicle communication.	Long Liu a,c , Jin Xu b,⇑ , Stephen Shaoyi Liao a,b,d , Huaping Chen c (2014).	• Real-time traffic information. • Distance. • Visiting behaviors of the self-drive tourists. • Visiting preferences of self-drive tourists.	Self-drive tourists, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), genetic algorithm (GA).
Using digital footprints for a city-scale traffic simulation.	Gavin MCardle, Eoghan Furey, Aonghus Lawlor, and Alexei Pozdnoukhov (2014).	• Social interactions and social influence. • Traffic flows. • Daily activities. • Travel distance and time.	Urban traffic microsimulation.
ABSTUR: An Agent-based Simulator for Tourist Urban Routes.	Iván García-Magariño (2015).	• Routes and their parameters. • Number of people sign up for certain tourist routes. • State of routes. • Types of tourists.	Software (INGENIAS).
A Multi-agent Based System for Route Planning.	Eugene Belyi, Indravan Patel, Anusha Reddy, and Vijay Mago (2015).	• Distance. • Speed. • Travelling time. • Environmental factors.	Multi-agent system, Bayesian network.

3.2 *Activity recommender system*

Some works present Multi-Agent Systems (MAS's) for addressing certain goals to provide a daily plan of activities that fit customers' preferences. For instance, Batet et. al (2012) present an Agent-Based recommender system called Turist@. The tourist interacts through a graphical interface with a User Agent that may be running in the user's mobile phone or Personal Digital Assistant (PDA). There is a Recommender Agent that stores the preferences of each user. These preferences are initialized with a brief questionnaire but are continuously refined and updated through the analysis of the actions made by the user in the system. The system provides proactive location-based recommendations, warning the user when it is near an activity that may be interesting for him/her. The items to be recommended are computed with a mixture of content-based and collaborative techniques.

Furthermore, Rodriguez et. al (2013) present a platform solution for fast building and automatic knowledge management of context-aware services for tourism in a novelty way, for indoor and outdoor environments. Their proposal consists of four key issues: generation and updating wayfinding mobile applications, automatic knowledge management, and multiplatform architecture available as native application, indoor and outdoor location and technologies applied to wayfinding functionalities (GPS, 3G, Wi-Fi, Bluetooth, and Qr-code compatibility). Table 2 reports the recommender systems found in the related literature, highlighting the criteria used in each case, as well as the tools used for implementation.

Table 2 Recommender system methodologies.

Title	Author	Criteria	Tools
Towards ubiquitous tourist service coordination and integration: a multi-agent and semantic web approach.	Dickson K.W. Chiu Ho-fung Leung (2005).	• Information gathering. • Preference matchmaking. • Planning. • Service brokering. • Commuting. • Mobile servicing.	Multi-agent Information System (MAIS) and Believe-Desire-Intention (BDI).
Agent Applications in Tourism.	Antonio Moreno (2007).	• Information about tourist attractions. • Making reservations or getting proactive personalized recommendations. • Location of the tourist and the activities.	Multi-agent system (MAS).
Turist@: Agent-based personalised recommendation of tourist activities	Montserrat Batet, Antonio Moreno, David Sánchez ⇑ , David Isern, Aïda Valls (2012).	• Information about tourist attractions. • Opinions of previous tourists. • Location of the tourist and the activities. • User profile and preference.	Multi-agent system (MAS).
GAT: Platform for automatic context-aware mobile services for m-tourism	M.C.Rodriguez-Sancheza, J.Martinez-Romob, S.Borromeoa, J.A.Hernandez-Tamamesa (2013).	• Tourist information. • Points of interest. • Location of guidance. • Indoor/outdoor route.	Multiplatform Application Generator (MAG) and an Information Management Unit (IMU).
Intelligent tourism recommender systems: A survey	Joan Borràs, Antonio Moreno, Aida Valls (2014).	• Interfaces (Web and a mobile). • Many possibilities of sharing information. • Information about the user's interests. • Similarity techniques.	Multi-agent system (MAS).

3.3 Hybrid recommender systems.

Sebastia et. al (2010) present a Multi-Agent System (MAS) aimed to support a user on the realization of different leisure and tourist activities in a city. The system integrates agents that cooperate to dynamically capture the user profile and obtain a list of activities for the user, by using the experience acquired through the interaction of the user and similar users with the system. Moreover, the system is also able to generate a time schedule of the list of recommended activities thus forming a real activity plan.

In addition, the work proposed by Noguera et. al (2012) consists of integrating a location-sensitive hybrid recommender engine with a custom-made 3D GIS architecture capable of running interactively on modern mobile devices. The proposed solution adapts the recommendations provided to users according to their current physical location. It also presents a rich and detailed virtual representation of the world where the tourists are currently located. The system fulfills the necessities required for on-the-move tourists: where they are, what interesting items can be found nearby, how far they are from them and how do they reach them. Table 3 reports the hybrid recommender systems found in the related literature.

Table 3 Hybrid recommender system methodologies

Title	Author	Criteria	Tools
A Multi Agent Architecture for Tourism Recommendation	Laura Sebastia Adriana, Giret Inna Garcia (2010).	• Types of tourists. • Opinions of previous tourists. • Create a suitable plan for each tourist.	Multi-agent system (MAS).
Multi-Agent Architecture with Space-time Components for the Simulation of Urban Transportation Systems	Quoc Tuan Nguyen, Alain Bonju, Pascal Estraillier (2012).	• Means of transport. • Attraction point. • Signs. • Road.	Multi-agent system (MAS).
A Mobile 3D-GIS Hybrid recommender system for tourism	José M. Noguera. Manuel J. Barranco Rafael, J. Segura, Luis Martinez(2012).	• Location. • Considered area. • Recommendable items. • Grouping users. • Distance.	Location-aware hybrid recommender system. Distance based re-ranking.

According to the literature, there are multiple methodologies offered as a solution for the lack of information about the activities and routes for tourists and considering their needs. Nevertheless, the approach of tourism-oriented works referenced in the literature review section is aimed at tourists who have the habit of pre-planning the routes and sites to visit on their trip, however, although this recommendation is adapted to the user preferences are not willing to change regardless of the different situations that occur in the environment, this recommendation remains static. On the contrary, our reactive approach is able to provide a different recommendation according to the time of the day in which the query is carried out since it takes into account what is happening in the environment and is able to adapt to provide a closer recommendation to reality. For this reason, the proposed approach seeks for embedding the route planning and the activity selection on a rolling horizon basis, which can be understood as a merge between the models reported in Table 3. Furthermore, these kinds of studies have not been implemented in Latin America, so the contribution of this work is to obtain an reactive ABM for the Colombian context in order to improve the experience of tourist and that is consistent with the reality of the environment, particularly for those who visit Bogota.

4. Case Study

The case study of this research proposal addresses Bogota, as the capital has a tourist potential, from different types of tourism, which allow economic and competitive development. Tourism in Bogota one of the sectors that is constantly growing in compare with different touristics sectors in Colombia (Antioquia, Bolivar, among others).For example, in 2017 the arrival of foreign non-resident visitors was 8,1 million and for 2018 this value was 8,5 million (Migración Colombia, 2018).

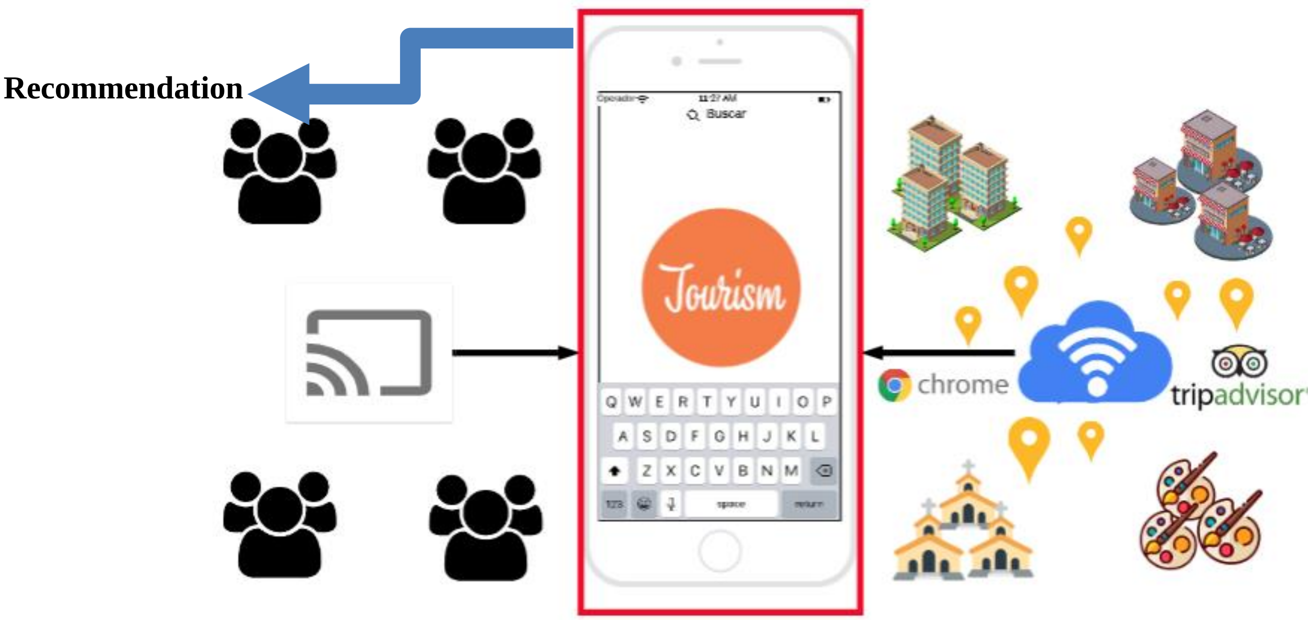
Besides, Bogota has a tourist information network that consists of a series of free, bilingual service points, in which national and foreign tourists receive personalized attention from tourism professionals with extensive knowledge of the city's tourist attractions. Into the city, there are routes, operators, scenarios, cultural activities, shopping areas, procedures, pedestrian routes and/or bike, among many more services that the visitor requires (Instituto Distrital de Turismo de Bogotá, n.d). In addition, Bogota has a variety of attractions for different types of tourists; for which the most iconic is La Candelaria.

Many of the buildings of La Candelaria neighborhood were built in colonial and Republican era styles and have been declared properties of historical and cultural interest. There are around 500 artistic institutions or groups, museums, research centers, theaters, libraries, and universities in this area of the historical center of Bogotá (Procolombia, 2019). For instance, in 2018, 1.9 million foreigners visited the capital, of which it is estimated that 80% visited the historic center (Arango,2019). For that reason, we consider La Candelaria as a dynamic scenario suitable for an Agent-Based Model.

As cities become increasingly competitive and complex, Information and Communications Technology (ICT) will coordinate all activities and services, leading to connected, better informed and engaged citizens. ICT make cities more accessible and enjoyable for both residents and visitors through interactive service interconnecting all local organisations to provide realtime services and use data centrally for better coordination (Buhalis et al. 2013).

The concept of Smart City represents an environment where technology is embedded within the city (Vicini et al. 2012). This technology will synergise with city's social components in order to improve citizens quality of life while also improve city services efficiency. From a tourism perspective, ICT could contribute in terms of generating value-added experiences for tourists, while also improving efficiency and supporting process automation for the related organisations (Werthner 2011). In Figure 1 shows the Smart City Environment.

Figure 1. Smart City Environment



For this work, will be performed a simulation of how tourism would work in La Candelaria will be carried out assuming that this location works under the concept of Smart City, which means that the model has real-time access to the relevant information for the recommendation made to each tourist. This information corresponds to: name, time, occupation of the site during the day, location and rating according to the opinions of tourists who have been on the site. For this, four platforms are recognized and used in Colombia: Booking, Despegar, Google and Tripadvisor. On these platforms people can find information related to hotels, transportation, restaurants and activities available to do or visit depending on the selected city. All those platforms allow tourists, who have visited the place, to assign a rating according to a prescribed scale, allowings future tourists to make their decisions based on historical experiences. The union of historical data collected by those platforms, and the recollection of real-time information based on the interaction of the User Agents with the environment-context, will allow tourists to have updated and close to reality information, fundamental in the decision-making process to build their tourist activity plan.

5. Metodology

5.1 Distributed artificial intelligence Paradigms

According to the aforementioned, Recommender Systems and/or Route Planning Systems have several variables, which make the simulation problem more complex. Contrary to classical centralized approaches, Distributed Artificial Intelligence (DAI) is an appropiate paradigm because DAI looks for a synergy between decisión and information. DAI can be defined as "the study, construction and application of multi-agent systems, that is, systems in which several interacting, intelligent agents pursue some set of goals or perfom some set of tasks" (Weiss,1999). One of the main ideas of DAI is the synergy, meaning that, when intelligences of each components are added up, this idle intelligence is less than the intelligence of the whole group combined, based on coordination and cooperation. For entities to be able to achieve the same goal, it is important that they can share knowledge by common ways of communications. The main distributed artificial intelligence paradigms are presented in Table 4.

Table 4 DAI Paradigms

DAI Paradigms	General Description
Multi-Agent Control Approach.	This approach use autonomous entities called "agents" that can act independently and take into account the environment.This attribute makes differentiates it from expert systems in which the decision making node or entity suggests for changes through a middle agent and does not directly influence the environment. This interaction is extremely important for this approach (Balaji et. al 2010).
Holonic Control Approach.	In a holonic system, an agent that appears as a single entity to may be composed of many sub-agents bound together by commitments (Balaji et. al 2010). Each holon appoints or selects a Head Agent that can communicate with the environment or with other agents located in the environment. This holons are able to cooperate with each other.This approach is a perfect example of combining pure heterarchy and hierarchy (Van Brussel et. al 1998).
Stigmergic Approach.	The term stigmergy refers to work that indicates how the communication mechanism is based on the traces that remain in the environment. This information stored in the environment forms a field that supports the coordination of the agent by stimulating its actions. The most popular example in nature is how ants behave when they find food. They secrete pheromones, these pheromones influence the following agents to obtain the same path. However, only the shortest path will end with the strongest pheromone distribution because it is the one that requires the minimun travel time (Iacopino et. al 2011).

To accomplish the first objective, various criteria for selecting a DAI method were considered. Different criteria were looked for to evaluate the usefullness of each method and which one fits better to solve the current problem:

- **Autonomy:** The behavior of autonomous entities can be based on both, their own experiences and the built-in knowledge used in constructing the entities for the particular environment in which they operate. Each decisional entity can work more successfully because they are capable of autonomous actions (Botti et al, 2008).
- **Reactivity:** An agent is responsive to events that occur in its environment, where these events may affect the assumptions that underpin the procedures that the agent is executing in order to achieve its goals. So, the effects of environment stimulus may be changes in the agent's goals or assumptions, or the agent's actions effecting changes in the environment. Such changes may affect their initial goals or prevent the execution of the current or future planned tasks (Botti et al, 2008).

- **Cooperation:** The cooperation is an imperative requirement for advanced intelligence systems. As well, all decisional entities cooperate to achieve the overall goals.

- **Hierarchy:** Is characterized as a different level of control and contain several control modules formed in a pyramidal structure. Each level has their own purpose and performance. The activities carried out by the "subordinates"are ordered by the "leader" and the "subordinates" have no choice but to comply. In the highest level of the pyramid there is a decisional entity that is responsible for create global goals and formulate means to complete them. The control decisions are operated top-down, with status reporting operating bottom up. (Galindo et al, 2016).

Multi-Agent Control Approach (MAS)

- **Autonomy:** Agents can operate without the direct intervention of humans or other agents (Botti et al, 2008). The use of agents has been successful in cases where there is high uncertainty or unpredictability, which requires autonomous processing units.

- **Reactivity:** Agents are able to perceive the environment's stimulus and these stimuli guide the agents 'actions in their environment (Botti et al, 2008),

- **Cooperation:** Is a key characteristic. There is repeated interaction between agents wich facilitates the achieve of the individual objectives.

- **Hierarchy:** Within the multi-agent behavior there is no defined hierarchy. Each Agent has the ability to formulate their objectives and carry out activities to achieve them.

Holonic Control Approach

- **Autonomy:** Has the capability of an entity to create and control the execution of its own plans and/or strategies (Botti et al, 2008).

- **Reactivity:** The Holons have the ability to change their plan according to the environment, however, it is less productive for the overall performance of the system. Holons work better following a plan (Botti et al, 2008).

- **Cooperation:** A set of entities develop mutually acceptable plans and executes those plans strategies (Botti et al, 2008).

- **Hierarchy:** There is a combination of hierarchy and heterarchy, each holon appoint or selects a Head Agent that can communicate with the environment or with other agents located in the environment (Van Brussel et. al 1998).

Stigmergic Approach

- **Autonomy:** Although each agent can act according to the traces that remain in the environment, the information they store allows them to send signals to the following agents that will enter the environment (Iacopino et. Al 2011).

- **Reactivity:** For stigmercial approaches, reactivity exists but "bypassing" the environment since each individual takes information from the experience in the environment of others.

- **Cooperation:** Works as a mechanism of indirect cooperation in which the trace left by an action in a medium stimulates a subsequent action (Heylighen,2014).
- **Hierarchy:** There is no hierarchy raised, but nevertheless the work done by one individual is enhanced by the work of others with complementary abilities in a way that the single individual never could have achieved (Heylighen,2014).

The Table 5 summarizes the evaluated characteristics of the paradigms.

Table 5 Paradigms comparison

Metodology	Autonomy	Reactivity	Cooperation	Hierarchy
Multi-Agent Control Approach (MAS)	■	■	■	□
Holonic Control Approach	□	■	■	■
Stigmergic Approach	■	■	■	□

After analyzing the different paradigms and considering tha case of study, it is necessary that the paradigm chosen to comply with the characteristics of Autonomy, Reactivity and Cooperation. However, for this phase of the project, the Cooperation will only be one-way, from the Place Agent to the User Agent.

Then, is explained why the Multi-Agent Control Approach is the paradigm that best fits the model:

- **Autonomy:** Each User is an independent Agent and its decision-making depends not only on external factors but also on Agent's own factors, such as its established pleasures and attributes.
- **Reactivity:** The recommendation that is given to the User Agent is on real time, meaning that the system must be able to adapt with the environment.For this reason, reactivity is essential in simulation, which is natural in the Multi-Agent approach, because of the stimulating environment influences of User Agents' actions.
- **Cooperation:** Although it is a key feature in simulation, the cooperation that exists in the system is in terms of the information that is collected and considered by User Agent’s for decision-making.It doesn't exist any cooperation beyond this, since it is not sought that the agents work for a common goal, but on the contrary that each one fulfills his individual goal.
- **Hierarchy:** It is not necessary to have a hierarchy within the system since all User Agents have the same importance, that is, each User Agent has total autonomy to meet its individual goals and do not need to be guided by others.

In addition, the use of Multi-Agent Approach has the following advantages and limitations that were having to be considered for implementation:

Advantages: The multi-agent system (MAS) paradigm emerged from the distributed artificial intelligence (DAI) field, in which autonomous entities, called agents, are organized in a decentralized structure (Leitao 2009). The first benefit of this paradigm is the representation of a physical object by an "agent", which according to (Ferber et. al 2004) is a virtual or real entity that possesses its own resources and skills used to pursue its own objectives. Thus, situation with different kinds of object, each one with its unique objectives, are likely to be represented by agent-based models. Second, an agent is highly dependent on its perception, and representation of the environment and other agents (Pichler 2000), wich reduces model complexity. Third, Agents organized in heterarchical structures are characterized by their high-level of autonomy and cooperation, restraining tight master/slave relationships. Information is handled locally and agents communicate with each other only if needed (Leitao 2009).

Disadvantages: As pointed out by (Mařík et. al 2005) the benefits of agent technology rely on the robustness, flexibility, adaptability and re-deplorability of the control structure. However, there are still some barriers to overcome (Leitão, Marik, and Vrba 2012) classified these issues in two groups: development- and conceptual-related aspects. Development-related restrictions arise from the lack of design methodologies and standards defining explicitly the structure of decisional entities, the cooperation methods, communication and interoperability protocols. Advances in commercial platforms and industrial controllers are also necessary to handle real-size industrial applications (Mařík and McFarlane, 2005). Conceptual issues are consequence of the high local autonomy. Since there is no central control element, these systems can be highly unpredictable and non-expected emergent behaviors can appeared, including chaotic behavior (Thomas, Trentesaux, and Valckenaers 2012). In addition to that, incomplete information make difficult to ensure that local decisions are globally coherent, thus it is hard to guarantee a minimum level of performance (Duffie, Prabhu, and Kaltjob 2002). Hence, global optimization is not possible, and conversely, local responses to perturbations can induce still larger perturbations in the system (Van Brussel et al. 1998).

Regarding the decision of the User Agent, different types of interactions with the environment were analyzed. Each of them is briefly explained below:

- **Belief Desire Intention (BDI):** This approach simulates human practical reasoning, they have an established set of beliefs, desires and intentions. In this case, the agents only consider the current state of the environment and its internal state. As the environment or system evolves, agent´s beliefs change. The plans and ways of acting change to adapt to the new situation of the system (Corchado, 1995).
- **Bidding-Based:** It takes specific behaviors or characteristics of some theme to reproduce it as close to reality, it is normally used to simulate scheduling and manufacturing processes. This approach does not have the common autonomy that agents normally have, since it depends mostly on the preset characteristics of the scenario to be replicated but allows the systems greater agility and intelligence (Gu et. al, 1997).
- **Contract Net Protocol (CNP):** In this approach, two types of roles are handled; manager or bidder and contractor, these two roles perform a bidirectional transfer of information, which allows them to solve problems that are processed in the environment. However, it is not

possible to define which agent will take on the role of manager or contractor because the CNP offers briefly outlined steps and processes (Wu, 2008).

- **Potential Fields:** It consists in the generation of an attraction field from the main agent to the receiving agent. The main agent sending a signal to the receiving agent, the magnitude of this signal may be greater or lesser than the internal attributes of the receiving agent. Although this signal influences the decision of the receiving agent, it has full autonomy at the time of decision- making.

The decision-making model chosen for the simulation was potential fields. This model can represent the dynamic tourism environment with the update of the field of attraction in real time.

In addition, the User Agent will filter those fields that match its interests. Therefore, each touristic place will create a potential field according to specific characteristics and this will increase or decrease depending on the changes that occur according to the simulation. One important factor for chosing potential fields is the one-way communication, since fields travel in one direction and User Agents sense them an make their decisions. This helps to reduce the amount of communication. To implement the potential field decision model in the simulation, three formulas were created based on the paper "*An effective potential field approach to FMS holonic heterarchical control*" (Pach et. al, 2012): **attractiveness, creation potential fields and selection place.**

Attractiveness

S: Set of sites S= {1, 2, …, |S|} denoted by the expression s∈S.
O_{ms}*:* Occupancy in the moment m∈M the site S∈S.
α_{ms}*:* Attractiveness in the moment m∈M the site S∈S.
P_s*:* Site Score of the site S∈S.
β_{mp} *:* Is a binary value set to 1 in the moment m∈M the site S∈S is open, else 0.

$$\alpha_{ts} = \left(\frac{\beta_{ts}}{1 + O_{ts}}\right) * P_s \qquad \forall_{m\in M}, \forall_{s\in S}$$

The *attractiveness* formula tells how attractive each site is at every moment, depending on the following input parameters: how full is that place at that moment of time of day, the score given by users who have visited this site and whether or not the site is open to the public. To calculate the attractiveness, it was assumed that the value of the score and the occupation used are the current values that will be provided by platforms such as Google and TripAdvisor, since the model is under the Smart City scenario.

Creation Potential Field

U: Set of turists *U*= {1, 2, …, |U|} denoted by the expression u∈U.
S: Set of sites *S*= {1, 2, …, |S|} denoted by the expression s∈S.
α_{ms}: Attractiveness in the moment m∈M the site S∈S.
D_{msu}: Distance in the moment m∈M between to the site S∈S and the tourist u∈U.
I_{su}: User interest of the tourist u∈U in the site S∈S.

A_{msu}: Is a binary value set to 1 if in the moment m∈M the tourist u∈U can pay the entrance to the site S∈S, else 0.

$$F_{tsu} = \frac{\alpha_{ts}}{D_{tsu}} * I_{su} * A_{tsu} \qquad \forall_{m\in M}, \forall_{s\in S}, \forall_{u\in U}$$

The *creation potential field* formula tells how attractive a site is for each specific tourist according to the following input parameters: how attractive the site is at that time (Attractiveness formula), the distance between the site and the tourist, the percentage of interest that the tourist has for that site and if the site is within the budget of the tourist.

Selection Place

$$SP_{mu} = argmax(F_{tsu} \forall_{s\in S}) \qquad \forall_{m\in M}, \forall_{u\in U}$$

Finally, the *selection place* formula is responsible for selecting the potential field with the highest value for each tourist in an instant of time.

5.2 Indicators

Within the simulation were designed some indicators that let evaluate how relevant is the recommendation throughout the simulation:

5.2.1 User Agent Satisfaction Level

TT_u: Total tourist travel time of tourist u∈U.
TTS: Total simulation time.
P_s: Site Score of the site s∈S.
I_{su}: User interest of the tourist u∈U in the site s∈S.
SM_u: Top Score of tourist u∈U.
$Scorea_u$: Tourist accumulated score of tourist u∈U.
Su: Percentage of satisfaction level by the tourist u∈U.

$$SM_u = \left(\frac{TT_u}{TTS}\right) * \left(\sum_{s\in S} I_{su} * P_s\right) \quad \forall_{u\in U}$$

$$S_u = \left(\frac{Scorea_u}{SM_u}\right) * 100$$

The satisfaction indicator shows the percentage of satisfaction that the tourist has at the end of the tour, according to the profiling. This indicator provides relevant information since if the tourist satisfaction is good, it means that the recommendation given adapts to the needs of the tourist and the characteristics of the environment.

5.2.2 User Agent Budget Used

BC_u: Percentage of the budget used by the tourist u∈U.

Bf_u: Final budget of tourist u∈U.
Bo_u: Initial budget of tourist u∈U.

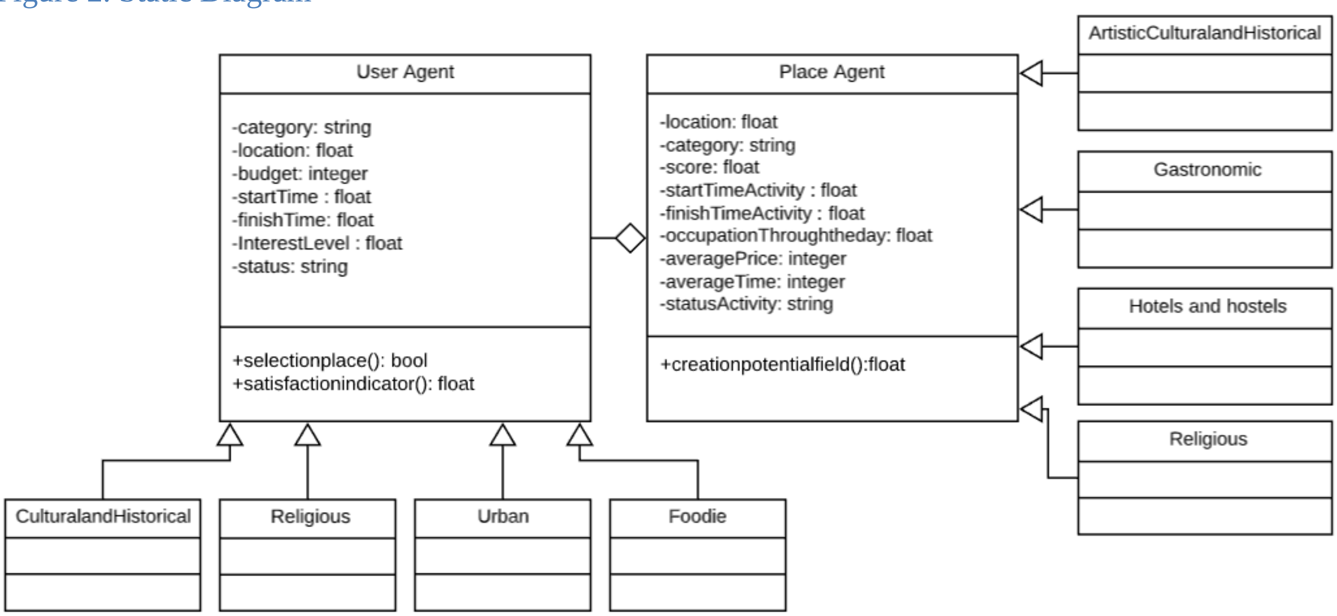
$$BC_u = \left(1 - \left(\frac{Bf_u}{Bo_u}\right)\right) * 100$$

The indicator of the percentage of the budget used indicates the percentage of how much budget the tourist uses during his trip. Which may represent an additional benefit for the tourist who uses the recommendation system.

5.3 Design and development of the recommender system

This section provides a thorough description of Agent-Based Model. First, the Agent-Based architecture of simulation is presented, and the functionalities of each of the agents are explained in detail. Figure 2 shows the architecture of Agent-Based Model, the model has been designed and implemented as a multi-agent system, with the following types of agents:

Figure 2. Static Diagram



- User Agents – There is one User Agent for each type of tourist that wants to access the system. It provides a graphical interface that offers several services, such as receiving personalized recommendations, searching for activities with characteristics or updating the profile (Batet et.al,2012).

- Place Agents – There is one agent of this kind for each type of places considered in the system. In the prototype that has been implemented, the places that have been included are Sights, Museums, Churches, Restaurants, hotels, hostels, and Theaters. Thanks to the system modularity and the flexibility of multi-agent systems, it is possible to add/ remove place types at runtime, adapting the system to cities, areas or daily changes (Batet et.al,2012).

5.3.1 User Agent

The User Agent associated to each user is the gateway for the tourist with the rest of the agents in the system. First at all, the User Agent is initialized at the according to tourist's degree of interest in specific areas such as History, Science, Music, Art, Cinema, Religion, Culture and Theatre. In order to ease sort tourists in the categories created, the Table 5 reports the profiles designed for the tourist.

Table 5 Tourist's Profile

Categories	Description
Cultural and Historical Tourist.	This type of tourist where the tourist is interested to visit heritage location, temples, churches, museums, forts, etc (Singh,2011).
Religious Tourist.	It is also referred as faith Tourist. It is a type of tourism where people travel individually or in a group for pilgrimage or leisure (fellowship) purposes.(Jalim,2018).
Urban Tourist.	This type of tourist activity which takes place in an urban space with its inherent attributes characterized by non-agricultural based economy such as administration, manufacturing, trade and services and by being nodal points of transport. Urban/city destinations offer a broad and heterogeneous range of cultural, architectural, technological, social and natural experiences and products for leisure and business (World Tourism Organization, 2018).
The Foodie.	This type of tourist where the food is the main motivation for travelers choosing their destinations. Travelers are spending more time and money on unique food and beverage experiences (World Food Travel Association, 2018).

Besides, we need other relevant information of tourist such as:

- Budget: Defines the amount of money the tourist is willing to spend, thus which activities can or cannot do.
- Location: It is important due to the distance can affect in the decision of doing an activity.
- Availability schedules: for each tourist it defines the amount of time to spend in different activities.
- Category: Defines which activities the tourist is interested on.

This information is used for each User Agent, and it furnishes an initial idea of the preferences of the tourist, that can be used to guide the personalized recommendations of the system. Nevertheless, the User Agent's information (Budget, location, places visited list, score and next destination) is frequently updated after each interaction of the tourist with the system. The interface provided by the User Agent allows the tourist to search for activities suitable for its profile according a given set of parameters:

- The User Agent cannot do the same activity twice.
- The cost of the chosen activities cannot exceed the budget of each User Agent.
- The User Agent cannot visit activities that are not available to visit at that instant of time.
- Once the User Agent enters an activity, the User Agent cannot leave the activity until it ends.
- The time it takes for the User Agent to visit the activities cannot exceed the total time to visit.
- The User Agent starts with a score of 0.0, which increases as he visits places throughout the

simulation.

- At the end of the available time of each User Agent, the User Agent must return to their origin point (Hotels, Hostels and bus station).
- When the User Agent chooses the destination to visit, he chooses the site that generates the greatest potential field according to his profiling.
- So that the model resembles reality in terms of the routes made by tourists, a network of links was designed, which function as streets or roads and will allow the User Agent to travel to the different activities.

5.3.2 Place Agent

Place Agents are generic entities that manage the information of attractions (e.g, Exhibitions, Museums, Cinema, Theatre, Sports, etc.). Each one has a local database in which it stores the information about specific events of a certain type that are going to take place in the city (Batet et.al,2012), in this case La Candelaria. In the current prototype, these local databases are fed with the information provided by the website. For this case the following information was considered:

- Location: It is important due to the distance can affect in the decision of do an activity.
- Category: It is defined according to the service that provides the activity (see Table 6).
- Score: Given by the other tourists and found on related websites.
- Openning hours: It is the time when the activity is available for public.
- Occupation through the day: It is an indicator of how crowded the activity is in specific time frames.
- Average price: It gives an estimated value so the tourist can determine its willingness to pay on the activity/service.
- Average time: It gives an estimated time so the tourist can determine its willingness to invest its time on the activity/service.

The Table 6 reports the categories designed of activities.

Table 6 Activity Categories

Categories	Description
Artistic cultural and historical.	This category has as primary purpose shows how other people or communities stay, survive and prosper. The kind of culture they practice their art and music is different from ours. So in order to acquire knowledge, understands culture well, to become familiar with the culture, they undertake journey (Singh,2011).
Gastronomic.	This category have attractions related to food for instance visits to food producers, food festivals and restaurants (Aiello,2014).
Religious.	This category is defined as any activity that primarily promotes or manifests a particular belief in or about a deity or an ultimate reality (US Legal, 1995).
Hotel and hostels.	This category has as primary purpose is to provide travelers with shelter, food, refreshment, and similar services and goods, offering on a commercial basis things that are customarily furnished within households but unavailable to people on a journey away from home (Sandoval,2016).

This information is used by the User Agent to know which the activity that best suits adapted to tourist preferences and making decision of which activity to do. In addition to complying with some restrictions:

• Place agents only generate potential field when they are available.
• Place agents are static throughout the simulation time, that is, they are located on a specific node in the network.

In Figure 3 is presented the process the User makes the decision of which activity to go.

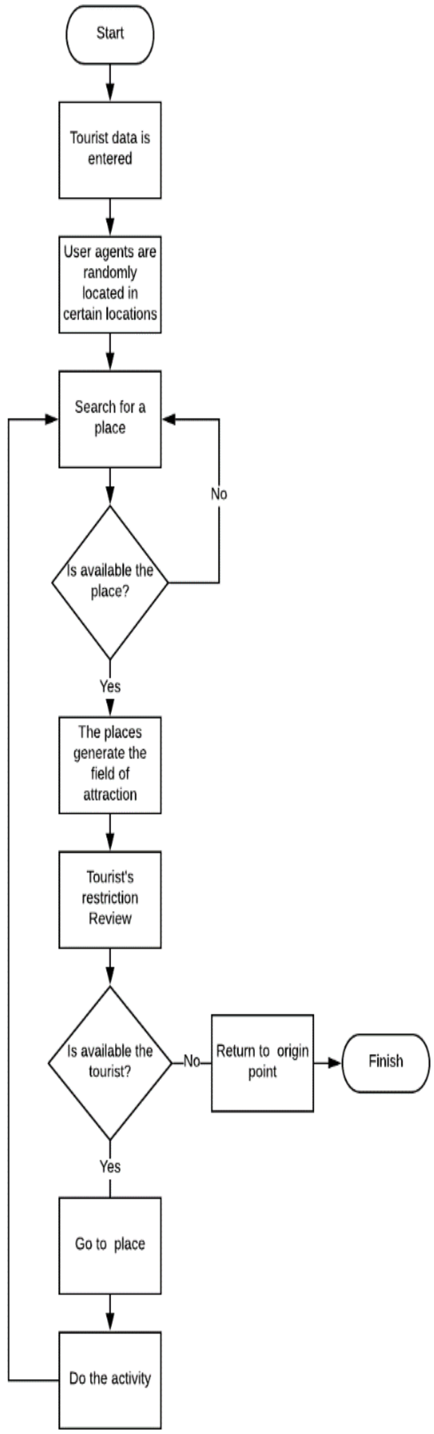


Figure 3. Dynamic Diagram

In Figure 3, the simulation begins when the user records the relevant data for the model, the model according to the data provided by the user, assigns it to each existing profile.To initialize the simulation, it was defined that the user agents will be randomly located at specific points such as hotels, hostels and Transmilenio stations. Subsequently, the activities found within La Candelaria will begin to generate a potential field which, will have less or greater attraction for the user agent depending on its interests. This potential field is generated with the *Creationpotentialfield ()* function. During the simulation time the potential field will change according to the conditions of each activity on a certain moment.

According to the potential fields issued by the activities that fit the user's preferences, the user agent will have to evaluate the site to be visited considering 1). The activity that generates more attraction and is available at that time. 2). That meets the restrictions set by the user. If it complies 1) and 2) the user agent will go to and enter the site with the *Selectionplace ()*. If it does not comply 1) it will carry out the search of the site to visit again. But, on the other hand, if it does not comply 2) the user agent will return to its point of origin and leave the system.

This process will occur for all user agents when deciding the next activity to perform.

5.4 Software Netlogo

Nowadays, the use of computer platforms and software have made it possible to simplify tasks, simulate or validate strategies during the design phase, correcting the errors before being deployed in the practical operation. However, the selection of this platform is not an easy task and more when it comes to a scenario that presents reactivity and adaptation. In this case, the modeling platform and ABM aims to test and compare the changes that are made to the parameters and decision-making algorithms of each agent (or of a specific race). Barbosa et. al (2010) after performing several surveys, they present a summary (Table 7) of the main criteria that the modeling platforms meet, on this ocassion were evaluated:

MASON (http://cs.gmu.edu/~eclab/projects / mason /), NetLogo (http: // ccl.northwestern.edu/netlogo/), Swarm (http://www.swarm.org/) and Repast (http://repast.sourceforge.net/).

Table 7. Characteristics of Some Agente - Based Modeling and Simulation Plataforms.

Name	*Mason*	*NetLogo*	*Swarm*	*Repast*
Availability (free)	yes	Yes	yes	yes
Maturity	-	O	+	O
Programming effort	-	+	O	-
Change of properties	-	O	-	+
User interface	-	+	-	+
Simulation speed	+	O	O	+
Documentation	+	+	O	O

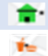
Legend: + Good; O Fair; - Poor

Analyzing the characteristics represented in the table it is possible to conclude that NetLogo platform is a good solution to develop Agent-Based solutions that exhibit complex behaviour. It provides an easy, intuitive and well-documented programming and modelling language with enough simulation facilities (e.g. a good graphical interface) and processing potentialities (Barbosa et. al, 2010).

5.4.1 Graphical Interface

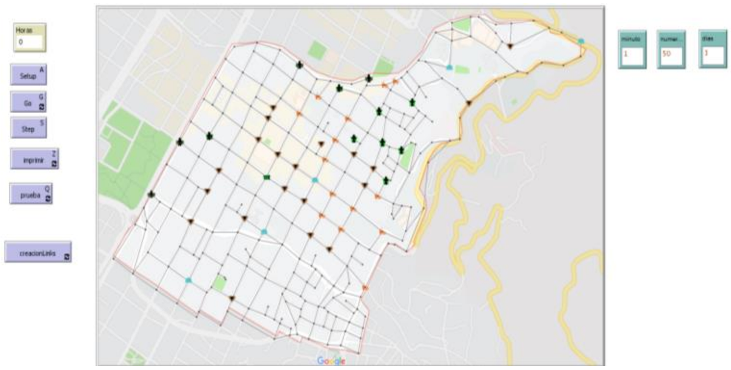
In the design of the Agent-Based Model, these icons were used to facilitate the control and monitoring of tourists during the visit of the different sites throughout the simulation. Table 8 shows the icons that represent the agents.

Table 8. Graphical components

Patches	Icons
Churches, museums.	
Hotels.	
Hostels.	
Restaurants.	
Bus Station.	
Node.	
User Agent.	
Links.	

The following picture shows a view of the Netlogo simulation in La Candelaria:

Figure 4. La Candelaria neighborhood



5.5 Assumptions

In order to simplify the Tourism simulation model in the Candelaria Neighborhood, the following assumptions were made:

1. It was assumed that the information of the score and the occupation of the sites taken from platforms such as Google and Tripadvisor will be updated in real time by these sites respectively, in accordance with the concept of connectivity of the information used in the Smart Cities. This will allow the recommendations of the model to be able to adapt to changes in the environment.
2. It was assumed that the budget parameters and the time available per day are distributed uniformly in order to allow all possible combinations to be presented and thus be able to cover all scenarios, given that actually are no data that can determine the behavior of these parameters.
3. In the same way, in the case of the distribution of tourist categories within the system, the uniform distribution was used to present all possible cases, therefore, the performance of the system is not affected by this aspect.
4. Simulation time per day lasts 15 hours, which starts from 6:00 a.m. at 9:00 p.m. When reviewing the opening hours of the 52 activities, it was not relevant to evaluate more of this time since, as observed, the offer of places to visit outside this time range is scarce.

5.6 Netlogo Model

The model consists of the following components:

- **The model considers quantitative and qualitative variables:**
  In Figure 5 and 6 show qualitative and quantitative variables for User Agent and Place Agent, can be observed within the simulation.

Figure 5. User Agent Information

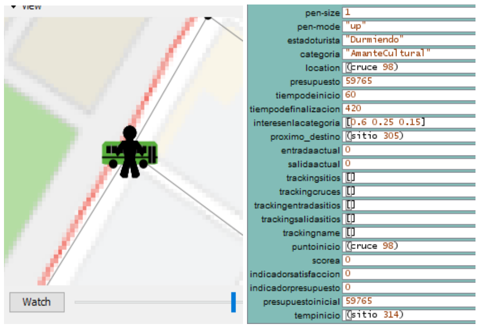
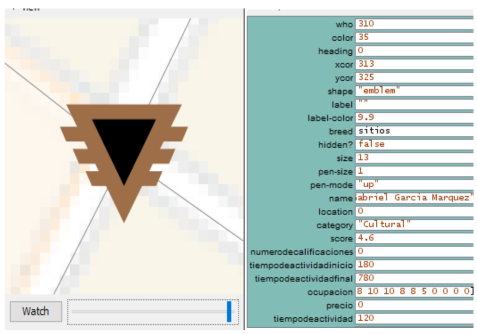


Figure 6. Place Agent Information



- **The model adapts to different scenarios:**
  Proof of concepts were carried out to check if the model's recomendations are consistent with the tourist's profile, different scenarios were considered: **1)** Number of tourists: 1, 2, 3, 4 and 10. **2)** Simulation time: 1, 2 and 3 days. **3)** Percentages of interest of the tourist towards the categories of places that are in the Candelaria. The results obtained for each category with their respective parameters and entry restrictions, such as the budget and tourist's available time. They were favorable since the sites visited by each User Agent fit the profiles assigned in the simulation. Table 9 shows some of the results obtained from proofs of concept performed on the model.

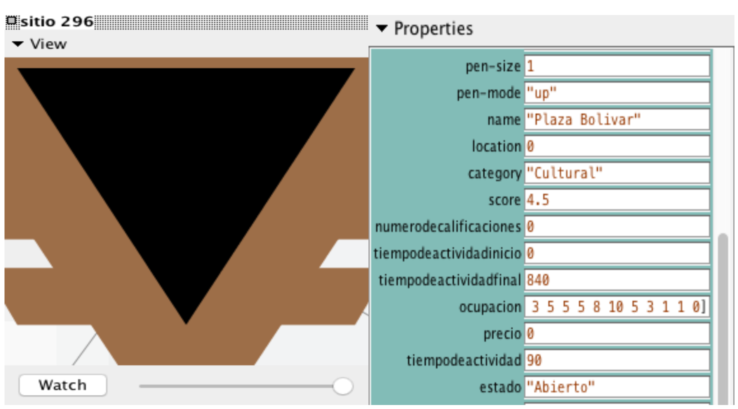
Table 9. Proof of Concept

Category	Available time (Hours)	List of visited places	Initial budget (COP)
Cultural and Historical	4	Museo Iglesia Santa Clara, Iglesia de la candelaria, Museo casa de la moneda	$ 106,875.00
Cultural and Historical	8	Plaza de chorro de Quevedo Bogota, Bike tours, Cacao+cacao, Museo casa de la moneda	$ 82,018.00
Urban	8	Sala Sekisano, Plaza de chorro de Quevedo, De untravel bar Casa vieja, Iglesia de la candelaria, Museo de Arte Miguel Urrutia	$ 109,678.00
Urban	8	Claustro de San Agustin, Plaza Bolivar, Museo arqueologico, casa del marques de San Jorge, Centro cultural Gabriel Garcia Marquez, Pizza madre	$ 52,770.00
Religious	6	Parroquia de nuestra senora de las Aguas, T Bone, Loto Azul, Museo casa de la moneda	$ 109,377.00
Religious	6	Iglesia de la candelaria, Museo Iglesia Santa Clara, Museo militar de Colombia, Museo de Arte Miguel Urrutia	$ 76,815.00
Foodie	8	Cacao+cacao, Cerveza Huitaca Pub, Loto Azul, Pizza madre, Centro cultural Gabriel Garcia Marquez	$ 145,963.00
Foodie	6	Casa vieja, Enchiladas la candelaria, Capital cocina y café, Pizza candelaria, Cacao+cacao	$ 222,507.00

- **The model generates a proper route for the plan of activities:**
  To offer tourists the shortest route, the model uses the dijkstra algorithm, which allows the tourist to travel less distance to the place that is more attractive according to their potential field.

- **The model considers the available hours for the activities recommended:**
  Each Place Agent saves the available time information for each site and is responsible for updating its status (open or closed) according to the time of day when the simulation is in and is taken into account within the recommendation, so that the recommended site does not exceed the time available to each tourist. This allows to calculate the potential field of each site when it is open. As can be seen in figure 7, the parameters of the place, in which the opening and closing time, in addition to the state of the Place Agent.

Figure 7. Place Agent's Parameters



- **The model must consult the opinions of tourists that had visited this activity:**
The tourist's opinions information that had visited this activity is taken from platforms tourism as Tripadvisor and stored for each Place Agent to calculate potential field of themselves.

- **The simulation environment must generate a performance indicator for the solution of each scenario:**
As for the simulation indicators, the model has two indicators: User Agent Satisfaction Level and User Agent Budget Used. Both are calculated and modified at the end of the established time of the simulation, which makes it possible to evaluate how accurate is the recommendation given to each User Agent or tourist.

5.7 Results and Analysis

The data taken for each instance consists of 30 replicas per day and the simulation covers a time range of 3 days, this data is discriminated in:

- Tourist (User Agent)
- Iteration
- Tourist Category
- Start Time
- Finish Time
- Simulation Time
- Church's Interest
- Gastronomy's Interest
- Culture's Interest
- Places Visited
- # Places Visited
- Score
- Satisfaction Indicator
- Initial Budget
- Final Budget
- Budget Indicator
- # Simulation Days

According to the results obtained (percentage of average satisfaction, percentage of average budget used, number of average activities, average time per day in the system, average score per category) in the different cases, we can observe that there are no significant differences between the results obtained in the instances, which allows us to conclude that the application's performance is not affected by the number of tourists who use it. Table 10 shows the results obtained with different instances.

Table 10. Results

Number of tourists in the system.	Category	Day 1				Day 2				Day 3			
		Budget Indicator Average	Average Satisfaction Indicator	Average number of activities	Score Average	Budget Indicator Average	Average Satisfaction Indicator	Average number of activities	Score Average	Budget Indicator Average	Average Satisfaction Indicator	Average number of activities	Score Average
5	Cultural and Historical	68%	34%	3	11,8	84%	47%	5	24,3	91%	73%	8	37,5
	Foodie	39%	54%	4	16,9	74%	70%	6	29,2	85%	88%	9	40,7
	Religious	30%	47%	3	12,7	63%	62%	6	26,1	73%	86%	7	33,5
	Urban	18%	36%	2	10,6	48%	57%	6	26,4	68%	81%	9	42,2
10	Cultural and Historical	31%	33%	3	11,7	60%	50%	6	25,9	81%	77%	9	40,3
	Foodie	72%	63%	4	17,9	89%	70%	7	32,5	93%	92%	9	43,9
	Religious	28%	50%	3	14,4	51%	67%	6	29,0	68%	88%	8	37,9
	Urban	39%	37%	3	12,7	66%	60%	6	26,2	84%	84%	9	41,5
20	Cultural and Historical	36%	37%	3	12,9	60%	53%	6	27,0	81%	79%	9	41,7
	Foodie	75%	63%	4	18,5	86%	75%	7	33,5	86%	91%	9	40,6
	Religious	31%	55%	3	16,3	58%	69%	6	29,1	72%	90%	8	38,9
	Urban	42%	41%	3	14,0	70%	62%	6	30,0	85%	86%	9	43,7
30	Cultural and Historical	34%	38%	3	12,8	62%	54%	6	28,1	81%	83%	9	42,8
	Foodie	75%	64%	4	19,0	87%	78%	7	33,7	88%	92%	10	44,9
	Religious	32%	56%	3	15,7	62%	71%	6	29,9	70%	92%	9	40,3
	Urban	47%	42%	3	14,1	72%	62%	6	30,0	85%	89%	10	45,2
40	Cultural and Historical	36%	39%	3	13,1	65%	56%	6	28,9	82%	83%	9	44,0
	Foodie	75%	64%	4	19,2	86%	78%	7	34,8	86%	92%	9	42,0
	Religious	35%	54%	3	15,4	58%	72%	6	30,1	68%	92%	8	39,4
	Urban	50%	45%	3	14,7	74%	63%	7	30,7	86%	89%	10	45,3
50	Cultural and Historical	37%	41%	3	14,1	65%	56%	6	28,9	82%	84%	10	44,9
	Foodie	74%	66%	4	19,4	88%	79%	7	35,2	88%	92%	9	41,5
	Religious	31%	56%	3	15,9	62%	72%	7	30,8	72%	93%	8	39,1
	Urban	47%	45%	3	15,1	74%	65%	7	31,3	87%	90%	10	46,5
100	Cultural and Historical	40%	41%	3	14,1	66%	58%	6	29,7	84%	87%	10	46,0
	Foodie	75%	66%	4	19,2	88%	81%	8	35,8	91%	93%	9	43,4
	Religious	38%	59%	4	16,7	61%	73%	7	30,8	71%	94%	9	40,9
	Urban	47%	45%	3	14,8	74%	66%	7	31,7	88%	92%	10	48,6

In addition, when observing the average satisfaction percentage obtained in the intances for each category, we see that the results are positive, which means that the precision in the recommendations generated by the application is adequate according to the time that each tourist has to visit the Candelaria

On the other hand, according to the results obtained, it can be observed that the consumption of more resources is not directly proportional to the level of satisfaction of the evaluated categories, except for the type of gastronomic tourism that has the highest values in both indicators. But this happens since this type of tourism tends to handle high prices compared to the other activities.

Based on the average number of activities, the level of satisfaction by category and the average time each tourist has been on the site. It is clear that in the 3-day time range for any category of tourism is where the highest level of satisfaction can be obtained, since there is more time for the tourist to visit the greatest amount of activities, however, the budget indicator consumed is affected since more resource is being used. According to this we recommend that the appropriate time to visit the Candelaria is 2 days, which allows to know a relevant number of activities and thus maximize the experience and expand knowledge about such an emblematic place for national tourism such as the Candelaria.

6. Conclusions and recommendations

6.1 Conclusions

- ✓ When evaluating the activity plan obtained at the end of the simulation for the different profiles, it is observed that the model complies with the restrictions stipulated in section 5.3.1. Likewise, the activity plan presents a balance of the places to visit, since on the route there can be more than one category of activities that fit the preferences and complement the tourist experience in La Candelaria.
- ✓ Although distributed artificial intelligence does not ensure optimality, based on the results it can be concluded that the model generates a coherent list of activities with favorable results compared to the profiles used in the simulation.
- ✓ According to the approach of generating recommendations in real time for each tourist, it is

appropriate to use the potential fields for decision making. Based on the results obtained, the performance was as expected, since that potential fields have been observed that it is easy to adapt to dynamic scenarios such as tourism, a sector that is characterized by being reactive and changing.

- ✓ It can be concluded that this model is the first simulator to simulate the behavior of tourism in La Candelaria taking into account different tourist profiles, segmenting activities according to what they offer and Given factors of the environment that influence the recommendation, which It enable to fit the scenarios presented and generates a recommendation that will accommodate the requirements of the user in real time.
- ✓ The work carried out is important since it can be used as a proof of concept that shows that through artificial intelligence distributed particularly of an interaction protocol such as potential fields, tourist routes can be built based on real-time information that meets with context restrictions and that meets the profiles of different tourists.
- ✓ Finally, the model has a potential use to complement current tourism platforms and even be the basis for the development of a new application. This would allow promoting the growth of tourism in La Candelaria since, although there is currently a large influx of visitors to Bogota. Offering a tool that allows to carry out an activity plan that suits the tastes and needs of the tourist in real time, increases tourist satisfaction and, consequently, the number of visitors continues to grow.

6.2 Recommendations

- ✓ It is recommended to use more powerful or advanced software than Netlogo, which allows the collection of information directly from the Internet so that the information is updated in real time.
- ✓ It is recommended that the tourist interest rate be dynamic throughout the interaction with the environment since this is closer to the tourist's behavior when making a decision and would allow the model to be able to predict these variations.
- ✓ It is recommended to give more relevance to places as they also provide relevant information about tourism behavior.
- ✓ For the qualification of the place, it is recommended to include the score of the tourists that are within the system with the value that is taken from the tourism platforms such as Tripadvisor, in order to have a more precise value. However, for this case it is necessary to re-evaluate the paradigm to be used since this level of cooperation resembles the Stigmergic approach.
- ✓ When recommending places, an additional parameter that can be included are the different events that exist to make a more attractive site, this can help enrich the tourist experience.

7. Glossary.

Agent Based-Modeling: System that is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions based on a set of rules (Bonabeau, 2002).

Multi-Agent System: Is a loosely coupled network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each software agent (IGI Goblal, 2013).

Netlogo: Is a multi-agent programmable modeling environment (Netlogo,2019).

Potential Fields: Potential fields is a technique originating from the area of roboticswhere it is used in controlling the navigation of robots in dynamic environments.

Recommender systems: Recommender systems are tools for interacting with large and complex information spaces. They provide a personalized view of such spaces, prioritizing items likely to be of interest to the user (Burke et. al, 2011).

Tourism: The act and the process of spending time away from home in search of recreation, relaxation and pleasure, while making use of the commercial provision of services (Walton, n.d).

Artificial Intelligence: The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from experience (Copeland, 2019).

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