How to integrate AI into Spatial Data Infrastructures: evolution of the Ucuenca SDI

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Abstract. The diffusion of great advances in Artificial Intelligence has managed to awaken interest in various lines of research and seek new ways for other fields of technology, seeking to make the most of these advances. Several of them have begun to become part of people's daily lives and there is no doubt that virtual assistants play a major role. Whether by the deployment of mobile devices for any user regardless of age, economic or social situation, it is common to have a computer. On the other hand, problems have been identified for citizen participation in territorial planning, and it is essential to seek forms of support in technology so that the use of these devices are not only for basic chat tasks but begin to be part of an intelligent citizen. In this context, Spatial Data Infrastructures need to evolve and take advantage of forms of AI to improve usability. This paper presents how the UCuenca SDI has evolved to integrate AI and the whole process that was necessary to develop a Virtual Assistant in a specific domain. It describes all the necessary steps that can be applied and that allow to continue growing the knowledge so that the use of AI allows a citizen to access geospatial information in an easy way. This contributes to the creation of working lines for smart cities, allowing the GADs to provide their citizens with adequate and more relevant information.

Keywords: Spatial Data Infrastructure, Virtual Assistant, Territorial planning, AI.

1 INTRODUCTION

A Virtual Assistant (VA) is a natural language processing software that includes text recognition, understanding, natural language generation, and text-to-speech transformation to enhance the interaction experience with users through questions and answers [1]. The literature review shows the direct relationship between geo-information and VAs is a relatively new field [2].

According to the accessibility of knowledge assistants, they can be divided into 2 main categories: open domain and specific domain. Open domain VAs can talk about general topics and respond accordingly. Specific domain VAs have been defined as bots that specialize in one area of expertise [3]. In the case of this document, it is the

specific domain, since the knowledge it handles is exclusively geoinformation related to the land use planning of the Cuenca canton in Azuay, Ecuador.

In the publication "Integrating a chatbot with a GIS-MCDM system" by Frei [4], types of Virtual Assistants are compared, where a primary classification of these is provided such as Customer Service, Social Networks/Marketing, E-commerce, among others, and this new paradigm of Virtual Assistant with an integration and interaction to geoinformation systems (GIS) is exposed. Frei categorizes these VAs as "Geobots", although in this article he does not describe implementation or development.

In the case of the most used and well-known Virtual Assistants in the environment, such as Google Assistant, Siri, Alexa, and Paval [5], these use skills from Google, Yandex and Apple, among others. To calculate distances, find paths, and review places, these use geographic services such as GPS (position) and Geographic Information Retrieval (GIR).

The most common use case of these assistants is for generic tasks such as searches for places of interest or specific addresses. Unlike what is proposed in this project, where mainly specific information is accessed, which is also located on servers of official institutions to which Google tools do not have access. Furthermore, in this case, the information to be accessed is specifically for territorial planning in the region. This is all the more reason why such information can only be found in specific sources that are accessible with the Ucuenca SDI. Facilitating access to geospatial information seeks to improve public participation and thus contribute to territorial planning [6].

On the other hand, to facilitate access to information, there are proposals to improve the usability of geoinformation systems or platforms [7]. A comprehensive solution to the challenges posed can be addressed by implementing a Virtual Assistant that facilitates access to geo-information and its visualization in a map viewer. This solution will provide an intuitive and user-friendly interface for users, including those with low technical and computer skills.

To organize and classify the geoinformation dispersed in the different generating entities [8], it is proposed to use the SENPLADES guide, which for the canton of Cuenca consists of the 6 planning axes for land use planning: biophysical, socio-cultural, cultural and patrimonial, economic, human settlements and relationship channels, land use and occupation [9]. This framework provides a unified structure for categorizing and labeling geospatial data. Furthermore, this classified data is used for training the Virtual Assistant, which improves its ability to understand queries and provide relevant answers.

Regarding the technological diversity of the geoservices, we have tried to solve this problem with the interaction of the Virtual Assistant. The Virtual Assistant is designed to interact with different technologies, such as WFS, WMS and ArcGIS tools, hiding these technical complexities from the user [10]. This will allow a seamless, and unified experience, where the user will be able to perform queries and obtain results regardless of the technology.

This solution achieves greater accessibility to geoinformation, effective data classification, and a simplified user experience, promoting citizen participation in the land use planning process, facilitating access to geoinformation, and contributing to a sustainable and planned development of the territories [6].

2 MATERIAL AND METHOD

2.1 Technologies used to update the UCuenca SDI architecture

The main tools that make up the UCuenca SDI are currently at the forefront of technology in the web development framework. By using Angular, IGO2, PostGIS, GeoServer, and Spring Boot tools in a geographic information system (GIS), several advantages are obtained that allow publishing and managing geographic information efficiently. In Fig. 1, the integration of these technologies can be seen.

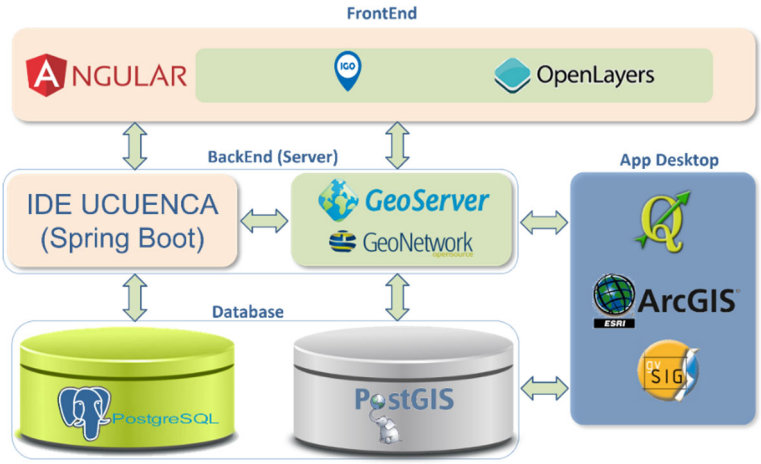

Fig. 1. UCuenca SDI implementation architecture

By using Angular as the web development framework, a modern and highly interactive user interface for visualizing and manipulating geographic data is achieved. IGO2, when integrated with Angular, provides specialized components and a coherent structure for the development of GIS applications, simplifying the building process and offering predefined geospatial functionalities. On the other hand, PostGIS, as a spatial extension of PostgreSQL, allows storing and managing geographic data efficiently, providing advanced spatial analysis capabilities. GeoServer complements this set by facilitating the publication and management of geospatial data through open standards, ensuring the interoperability and accessibility of maps and geospatial layers. Finally, Spring Boot offers a robust and scalable framework for developing microservices-based Java applications, providing easy configuration and security features to protect sensitive geographic information.

The combination of all these tools enables the creation of powerful and flexible GIS systems, providing the ability to efficiently publish, visualize and manage geographic information. They provide a solid foundation for the development of modern, scalable GIS applications, facilitating interaction with spatial data and improving the user experience in the visualization and manipulation of maps and geospatial layers. Added to this is the advantage that the tools used are open source.

2.2 Virtual Assistant System Architecture

In the process of updating the UCuenca SDI, the Virtual Assistants functionality was included. The proposed architecture evolved as the project progressed, and after two versions the final architecture was achieved.

In the first version, the scheme focused on conversations based on a direct co-connection to the information of the Municipal Government of Cuenca and on the use of meta-data of the information published both at the citizen and technical levels. In the second version, the functionality of identification by planning axes was added. This process is explained in [11].

However, when analyzing the previous architectures, the large amount of geoinformation and the need for greater granularity in the classification is evident. To solve this problem, a sub-level was sought that would classify the geoinformation within the axes, leading to the creation of the Sub-Axis label, which will be unique, allowing a more accurate classification. For the creation of the Sub-Axis, the "Keyword" column of the geoinformation matrix was taken and was based on the "Diversification of Territories of the Provincial Government of Azuay" [12], resulting in the creation of 132 sub-axes that can be observed in Table 1.

Table 1. Axes and sub-axes of planning

Physical environment	**Socio / cultural**	**Cultural / heritage**	**Economic**	**Human settlements and channels of relationship**	**Land use and occupation**
Geology, Soils Climate, Water (Watersheds, hydrographic network) Protected Areas Water Quality Air quality Noise Flood Risks Risks Mass movements seismic risks, Volcanic hazards Drought risks Landslide and Downside Risks Mining Vegetation cover Biosphere Hydrography Fire Water awards Green areas Mountains and hills	Population demographics growth rate, natality mortality ageing index, Life expectancy Population development bonds Social organizations Occupation category Identification Population by Sex	Historic areas Cultural heritage Natural Heritage (INPC)	Economic activities Tourism	Equipment E. Health E. Education E. Social Welfare E. Culture E. Recreation and sport E. Security E. Procurement E. Service E. Collection Basic services Road infrastructure/public transport: stations, routes, etc. Telecommunications: telephony, internet, electric power Hierarchy of settlements human settlements	Building permits Land use Industrial Zone Agricultural Zone Livestock Zone Residential area Area of exploitation of arid materials Oil exploitation area Conservation area River protection margins Land occupation Pharmacies Land use conflicts Small industry Large industry

It should be noted that at this point of the development, the geoinformation matrix was written in the technical language of professional areas such as Architecture and Engineering. As a solution to this, a field exploration was carried out with the objective of

understanding in depth the dynamics of communication and the use of language by the communities involved in the project. This field exploration consisted of direct interaction with the members of the communities [13].

With the purpose of verifying the functionality and applicability of the Virtual Assistant, direct meetings were held with members of the communities of the parish GADs of Baños, San Joaquín and Sayausí, where interviews, and observations were applied. In this way, empirical data was collected on communication practices and the type of language used in different territorial planning contexts of these communities. The results of these interactions with the communities were twofold: the first is that the citizen does not handle the concepts of what a Planning Axis is and the second is the use of local jargon in their speech. For example, there are roads in Cuenca that are colloquially called "Autopista" or "Circunvalación", while in the data collected, they appear as "vía estatal E35" or "Panamericana N o S", which should have a different processing and treatment. The same is true for the Cajas National Park, which needs a more granular approach to facilitate the identification and search for information specific to that territory, providing users with a more efficient and personalized consultation experience.

Likewise, it was realized that the query entered into the Virtual Assistant in technical language should reach the same information as a query formed in natural or colloquial language. For example, if an architect searches for "Red de Transdistribución", it is the same as what an ordinary citizen understands by "electrical network cables" colloquially called "light poles". To solve these problems, the whole architecture was redesigned around the input message from the user to the Virtual Assistant, i.e., what are the message and the intention of consultation or search for geo-information that it contains, processing it regardless of the use of technical language, natural language and local jargon in the input message. From this input message, the geoinformation and the place that the user wants to see on the map are identified and extracted, with this data the Virtual Assistant retrieves the geoinformation from the spatial database, verifies the availability of the geoservice of the institution, and loads the geospatial data to the map viewer of the UCuenca SDI.

Finally, it generates a response in the wizard window with a link to the geospatial data viewer with the response and always leaves open the possibility of entering another message, thus achieving a fluid conversation between the wizard and the citizen. The new architecture is shown in Fig. 2.

With this architecture, the integration of the Virtual Assistant with the geoservices of the UCuenca SDI and the geoinformation generating institutions and their implementation technologies was achieved.

The flow of information in the Virtual Assistant architecture is detailed below:

Step 1: From the front-end of the UCuenca IDE, the input message is sent to the Virtual Assistant through a communication socket.

Step 2: The VA Engine interprets and analyzes the message, within this step the search intent contained in the message is extracted.

Step 3: The VA Engine elaborates the query and executes the necessary steps to form the response.

Step 4: The geoinformation is retrieved according to the search crime, from the spatial database of the UCuenca SDI, such as id, title, type, and the URL of the geoservice.

Step 5: Verify the availability of the institution's geoservice.
Step 6: Select the map viewer and communicate with the UCuenca SDI to load the layers with the geoinformation retrieved in step 5 and 6.
Step 7: Create the link and generate a response to the user.
Step 8: The response is sent to the user in the front-end of the UCuenca SDI through the socket created in step 1.

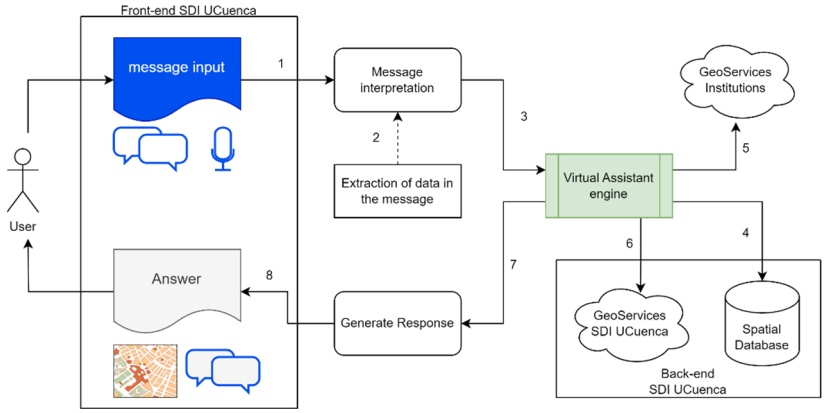

Fig. 2. Virtual Assistant System Architecture

For the deployment of the Virtual Assistant on the physical server, it is necessary to consider that the other SDI services such as the map viewer, and the spatial database, among others, are also hosted on the UCuenca SDI server. Therefore, an architecture based on docker-compose containers has been proposed to achieve an independent and resilient environment.

2.3 Virtual Assistant Design and Modeling

Data preparation, which involves the organization, data classification, and semantic enrichment of the labels that will be used both in the SDI and in the training, share the same processes, up to the level of classification in land use planning axes. This classification can be visualized in Fig. 3. It is worth noting that the level of sub-axes (Table 1) is used for the Virtual Assistant training.

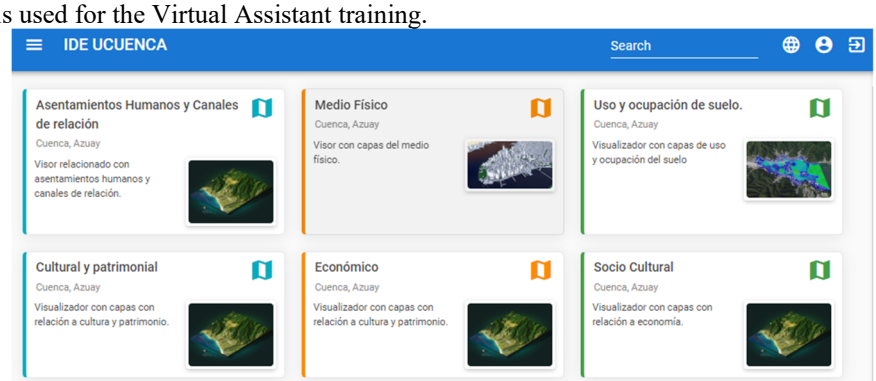

Fig. 3. Capture of the UCuenca SDI viewers

Once the data has been cleaned and prepared, and the architecture has been proposed, we proceed to the design of the Virtual Assistant, which consists of 3 phases:

a) Conversation design

One of the key points for a smooth and coherent operation of the Virtual Assistant is the correct understanding and follow-up of the conversation, for which the following considerations were taken into account:

- A logical order of interactions and possible ramifications.
- Define the user's input messages and the VA's responses at each step.
- Determine the specific objectives of the conversation, i.e., what each interaction is expected to accomplish. This may include providing information, taking action, or resolving queries.
- Design clear, concise, and relevant responses for each situation. These responses should be tailored to the identified intentions and geospatial data, providing the required information or performing the actions requested by the user.
- Take into account the context of the conversation, i.e., previous information or events that may influence the current interaction.

Four main interactions were considered: initial greeting, making a request, requesting the help section and requesting unrelated information.

b) Modulation of VA components

To achieve the goal of the conversations, the Virtual Assistant was built using several components and 3 main modules. These components are distributed among the 3 modules called Rasa NLU, Rasa CORE, and Action Server that make up the VA Engine architecture [14].

To analyze the geo-query we use the tokenizer to separate the entered message word by word. (see Fig. 4).

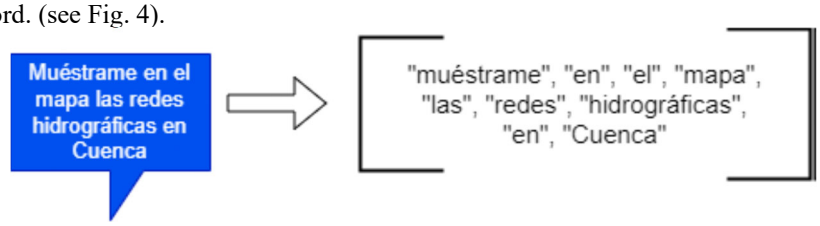

Fig. 4. Tokenization of an input message

Then, by means of the different Pipelines components, Rasa NLU converts the unstructured or misspelled messages coming from the user so that they can be classified according to the knowledge base format, by means of the DIET component, as shown in Fig. 5.

Throughout this process, Rasa NLU and Rasa CORE work together as an integral component of the system to elicit search intent and extract key information from the

message. At this point, the previously defined policies come into operation that carries out a memorization subprocess where the neural network continues to learn as new inputs are received and outputs are generated [15], [16].

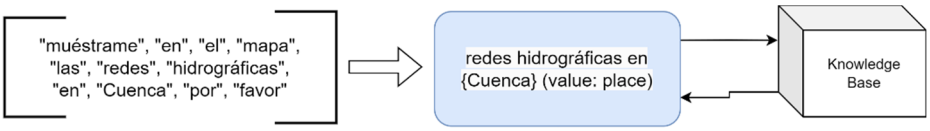

Fig. 5. Extract important phrase for classification

c) Design of the methods of interaction with the Virtual Assistant

The design of the Virtual Assistant interaction and communication methods is carried out with several important considerations in mind:

- The ways in which the user can interact with the Virtual Assistant are considered text and voice.
- Which UCuenca SDI service will be used to offer the Virtual Assistant?
- The programming language to be used for front-end and back-end.
- Communication protocols between front-end and back-end.
- Handling multiple conversations.
- Design of the graphical interface with familiarity with the entire Project.

2.4 Wizard Training and Programming of Custom Functions

Since there was no knowledge base, RDF schema or ontologies on the subject of land use planning for the canton of Cuenca, a knowledge base was created from scratch.

Several steps were followed to generate this knowledge base and the neural network for decision making. First, examples of dialogs were created to represent the different search intentions and entities that the Virtual Assistant must recognize and interact.

The formation of this set of examples contains representative and diverse sentences that encompass the different ways in which users, both technical and ordinary citizens, can express their search intentions, for example:

- I want to see parks in Monay.
- Show me trans-distribution networks.
- Density of older adults in Cuenca.
- How does SDI work?
- Relief of El Cajas.
- Highways in Cuenca.

These examples were created following a manual process, creating a phrase bank based on planning sub-axes, synonyms, questions, and different ways in which a user can refer to the geo-information they wish to see on the map. Within these examples, special places and local jargon were considered and would be implemented using the components of the NLU module.

To implement the knowledge base for the Virtual Assistant a supervised training process was followed, in this case, there are 1056 examples of input sentences and the

132 planning sub-axes were used as output. The objective is for the model to acquire the ability to classify an input into an Intent. This Intent is defined as the geo-information search intent based on the planning Sub-Axes. Each Intent contains between 5 and 12 example sentences.

Next, the corresponding training files are created to define the inputs and outputs nlu.yml is created. For the AI model that makes the decisions in the Rasa CORE module, the stories.yml and rules.yml files are created. Finally, to define the knowledge area, the domain.yml file is created, where the search intentions, entities, personalized actions, predefined answers, and answer generation are defined.

2.5 VA Deployment and Integration with the Spatial Data Infrastructure Portal

For the deployment of the Virtual Assistant on the physical server, the coexistence of other services of the project, such as the Geoserver, Geonet-work, PostGIS for the spatial database, and nginx, has been taken into account. The deployment architecture is shown in Fig. 6. This diagram represents the implementation of the physical server and the interconnection of the different services with the Virtual Assistant.

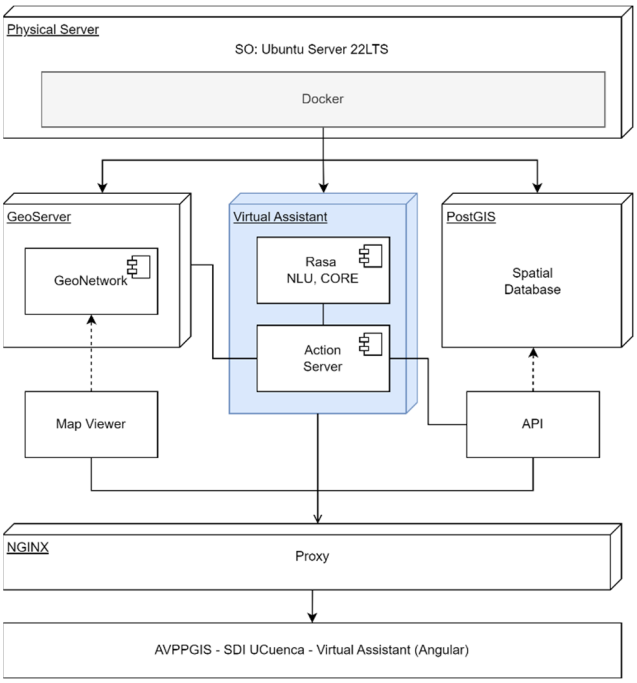

Fig. 6. Physical server implementation diagram

To achieve an independent and resilient environment for each system, a Docker-compose container-based architecture was proposed. In this architecture, each service is deployed individually in its own Docker container, providing an additional level of isolation and flexibility.

3 RESULTS

The results obtained with the development of the Virtual Assistant were: a) the training of the data for training, b) the creation of the knowledge base, c) the design of the training and the creation of the AI Model for decision making, d) the HCI design and e) the implementation with a graphical interface of the Virtual Assistant in the geoportal of the UCuenca SDI.

The creation of the geoinformation knowledge base through Rasa NLU consists of two processes: the training of the input and output examples following supervised training and the choice of the eight implemented components for the creation of the same. 1056 example sentences were manually created for each planning sub-axis, these examples include natural language, geospatial technical language, and jargon used in the Cuenca canton, in union with the different implemented components.

The creation of the AI Model consists of the design of the conversations in the stories.yml file, the rules that the Assistant must follow, and the implementation of the execution policies in conjunction with the Knowledge Base resulting in the neural network of hidden layers called "AI Model for Decision Making". With the iteration of the AI model packaging, the more interactions you have, the more model files are created.

Deployment of the Action Server, in charge of executing the personal functions of the assistant such as data retrieval from the spatial database implemented in the UCuenca SDI, loading the layers to the map viewer, verifying the availability of the geoservices of the institutions and the formation of the data of the answers that will arrive to the user when he/she makes a query to the Virtual Assistant. With the results obtained in the analysis and development of the Virtual Assistant, the Virtual Assistant was deployed in the UCuenca SDI geoportal (see Fig. 7).

Fig. 7. Virtual Assistant highlighting how it works in the geoportal

The graphical interface of the UCuenca SDI is adequate, without detracting from the map viewer, and has the option of minimizing the Wizard for a complete visualization of the map, (see Fig. 8**).**

Fig. 9 shows the Virtual Assistant deployed and implemented in the UCuenca SDI. The user performs an interaction with the Virtual Assistant through the back-end, to execute geo-information queries. The message is processed, the service is retrieved and validated, layers are loaded to the viewer and the response is generated to the user (see Fig. 10**).**

The Virtual Assistant meets the following HCI functionality considerations (see Fig. 11):

- Availability on any type of browser connected to the Internet.
- The Virtual Assistant window is responsive, and runs correctly on PC and mobile devices.

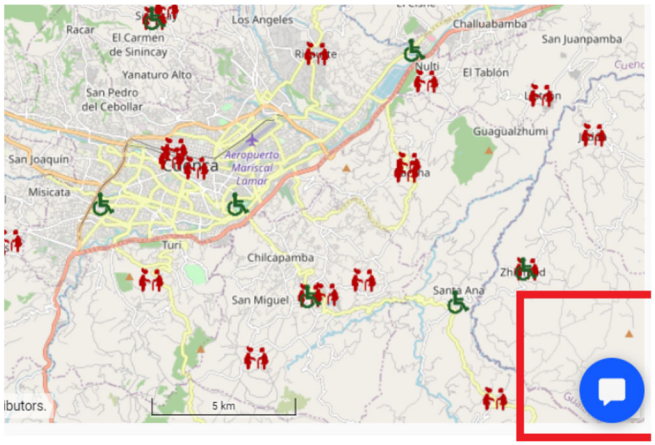

Fig. 8. Virtual Assistant minimized

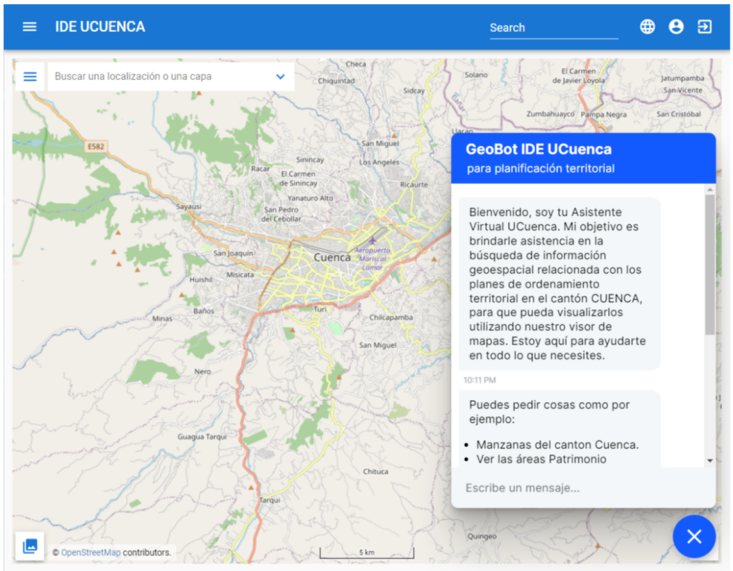

Fig. 9. Virtual Assistant integrated to the UCuenca SDI

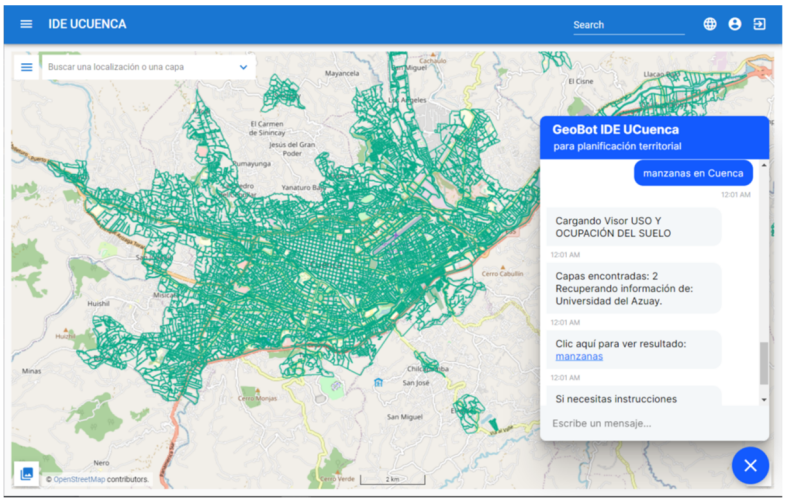

Fig. 10. Interaction with the Virtual Assistant at UCuenca SDI.

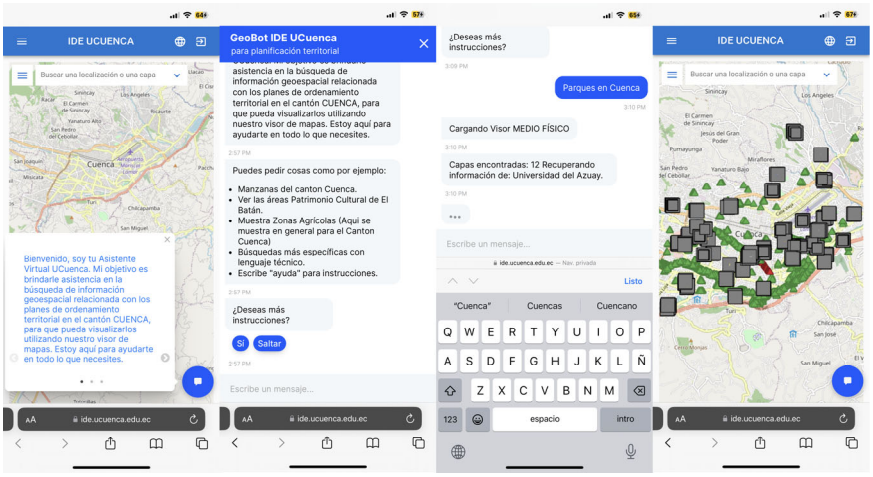

Fig. 11. Functional Virtual Assistant at UCuenca SDI.

4 EVALUATION

Technical usability tests were performed in the production environment. These tests were performed successfully with 9 devices: 5 computers (3 Windows, 2 Linux, and 1 Mac) with 3 different browsers on each one (Chrome, Firefox, and Brave) and 4 cell phones with their default browsers (see Table 2)

Table 2. Usability tests

Browser	Geoconsultation	Unrelated query	Informational question
Chrome	5 interactions	7 interactions	7 interactions
Firefox	7 interactions	5 interactions	7 interactions

Brave	6 interactions	5 interactions	8 interactions
iPhone (Safari)	3 Interactions	3 Interactions	3 Interactions
TOTAL	21 Complete Interactions	20 Complete Interactions	25 Complete Interactions
		TOTAL:	66 interactions

To measure the ease of use, an appreciation survey was applied to 15 potential users with different profiles. The survey consisted of 8 questions.

Table 3 shows the summary, which allows verifying that the Virtual Assistant meets the objective of facilitating access to geospatial data through an SDI.

Table 3. Ease of use

QUESTION	Level of appreciation (max. 5, min. 1)				
	5	4	3	2	1
Did the Geobot facilitate the use of the SDI?	93%	n/a	n/a	n/a	7%
Were the Geobot's answers useful?	40%	53%	7%	0%	0%
Was the search process with the geobot fast?	33%	n/a	67%	n/a	0%
Is the GeoBot interface easy to use?	93%	7%	0%	0%	0%
Were the instructions for the use of the geobot useful?	20%	73%	7%	0%	0%
How often does the GeoBot "hang" or "not respond"?	0%	0%	0%	0%	100%
How satisfied are you with the performance of the Geobot?	80%	13%	7%	0%	0%
Would you recommend the use of GeoBot and the UCuenca SDI instead of other geoportals?	47%	33%	7%	0%	13%

5 CONCLUSIONS

The UCuenca SDI geoportal has a Virtual Assistant for geoinformation consumption of the canton of Cuenca, providing a tool for the benefit of citizen participation processes in land use planning. The information coming from the geoinformation generating institutions has been filtered, organized, classified, and purified, achieving a first level of standardization that guaranteed the coherence and consistency of the data, improving the accuracy and reliability of the Virtual Assistant training, allowing the creation of the spatial database and its relationship with the layers integrated into the SDI.

The choice of Rasa open-source as the development framework for the Virtual Assistant demonstrated its ability to integrate specific domain knowledge, allowing greater control over the design and logic of the VA. The result was a more personalized experience tailored to the specific needs of the land use planning case study.

A knowledge base was created specifically for RASA, since there was no knowledge base for land use planning in the canton of Cuenca, standardizing the information from the 14 geoinformation generating institutions. By using Docker-compose containers, easy management and scalability of the services were achieved.

If any of the components, be it the Virtual Assistant, the map viewer, or the spatial database, should spatial database, experiences a vulnerability or crash, the other services will continue to function independently, preventing a failure from affecting the entire system. This improves overall system availability and resilience.

The integration of the Virtual Assistant to the UCuenca SDI map viewer allows common users and technical professionals in territorial planning to have a more fluid and

efficient user experience. This Virtual Assistant is able to manage the information received from different public and private entities and perform queries to display the results in the map viewer.

It is worth noting that every time a citizen uses the Virtual Assistant, it continues to add knowledge to the Virtual Assistant, this process is based on the feedback provided by users and the experience accumulated over time. The neural network analyzes and processes this information to adapt and improve the answers provided, which contributes to a more fluid and accurate interaction with users. The design of the Virtual Assistant with the UCuenca SDI facilitates the user to search in a satisfactory way for any type of geo-information within the axes and sub-axes of planning, likewise the accessibility is transparent, that is to say, it does not require knowledge of the management of a SDI, nor of the technical language of this area.

The Virtual Assistant is available to work in any internet browser. The graphical interface of the Virtual Assistant allows it to adapt to any size, screen resolution, and windows. A final advantage is that the Virtual Assistant has in guaranteeing answers, either with the requested geoinformation or answers in context to the conversation, no matter how many requests are being addressed, there are no interruptions in its operation.

Acknowledgment

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