GeoSpatial Conversational Agents
Empowering Rural and Urban Sustainability in India

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Abstract

India's diverse landscape and complex socio-economic challenges necessitate innovative solutions for sustainable development. Geospatial technologies offer a powerful tool to address these challenges by providing accurate, timely, and actionable information. This paper proposes a framework for developing Geospatial Conversational Agents tailored to India's specific needs, by integrating generative AI with geospatial analysis.

By leveraging advanced technologies such as artificial intelligence (AI) and large language models (LLMs), integrated into agentic workflows that are grounded in geospatial data, these Geospatial Conversational Agents aims to empower users with geospatial insights to support sustainable decision-making. Further, by integrating natural language processing (NLP) techniques, enables to understand and respond to user queries in both text and voice formats, in their regional languages. This accessibility will enable a broader range of users, including policymakers, researchers, and the general public, to harness the power of geospatial data to make informed decisions and contribute to sustainable development goals.

The framework is capable of addressing a wide range of geospatial queries, including water resource management, snow covers, urban planning, etc. It processes satellite data from platforms like Sentinel and Bhuvan to provide real-time information. For instance, it can estimate water levels in reservoirs like Hirakud, analyze crop health, or predict flood-prone areas. This initiative aligns with several Sustainable Development Goals (SDGs), including clean water and sanitation, sustainable cities and communities, and climate action. By providing timely and accurate geospatial information, the ChatBot (Geospatial Conversational Agents) can support evidence-based decision-making and contribute to India's sustainable development goals.

1. Introduction

In the age of instant communication and smart technology, Conversational Agents are becoming indispensable tools, bridging the gap between users and location-based services. Conversational Agents or Chatbots are computer programs designed to simulate conversation with human users, especially over the internet. They use artificial intelligence (AI) and natural language processing (NLP) technologies to understand and respond to user queries or commands. Conversational Agents or Chatbots are used in various applications, from customer service and support to information retrieval and task automation. These intelligent assistants provide users with valuable information, navigation, and recommendations tailored to their specific requirements. Geospatial Conversational Agents offer a user-friendly and interactive way to access and visualize geospatial data, making it more accessible to a wider audience. By incorporating features that provide insights into various aspects of the environment, such as waterspread of reservoirs, agriculture, watershed, and built-up area, these AI Agents can enhance decision-making and promote sustainable development. They can serve as valuable tools for environmental monitoring, resource management, and sustainable development initiatives. Additionally, while working, we also identify that India's linguistic diversity, with 22 officially recognized languages and hundreds of regional dialects, necessitates Geospatial Conversational Agents or Chatbots that cater to users in their preferred languages, enhancing accessibility and user experience. Also, understanding local culture is crucial for providing relevant recommendations and services. Geospatial Conversational Agents can be customized to offer culturally sensitive information based on specific regions within India. Therefore, by providing accurate information, promoting local businesses, supporting rural development, and ensuring efficient access to essential services, the geospatial chatbot will be a powerful tool for empowerment and inclusivity in one of the world's most vibrant nations. Embracing the unique challenges and opportunities presented by India, the specialized chatbot stands to revolutionize user experiences and contribute to the nation's technological advancement and societal well-being.

The organization of the paper is follows: Section 2 discusses the related works, in section 3 we present the scope followed by the proposed framework in Section 4. Section 5 contains the technology stack used in designing followed by sections 6 & 7 on development and implementation of Geospatial Chatbot while sections 8 & 9 discuss Privacy, and Security and User Experience respectively. In section 10 we present our some of our results followed by conclude remarks and the future scope of the geospatial chatbot in section 11.

2. Related Works

While working in this area we referred a few research articles related to geospatial chatbots and conversational AI technologies. In (Charlotte 2021) author had investigated whether a humanlike communication style enhances users' chatbot and brand perceptions. Two experiments were conducted in which the effects of informal language (vs. formal language) and invitational rhetoric (present vs. absent) were examined separately. In both experiments, participants engaged in conversations with a customer service chatbot in the tourism sector after which they evaluated social presence and attitude towards the brand. While in paper (Guoray et al 2005) authors presented a conceptual framework for enabling conversational human- GIS interactions. Conversations with a GIS are modelled as human-computer collaborative activities within a task domain are also covered. The article by (Torous et al 2022) provides an overview of the use of chatbots and conversational agents in the field of mental health, exploring their potential applications and challenges. Understanding of the user experience of chatbots for customer service is essential to realize the potential of this technology which are discussed in this paper (Kathleen et al 2022). Such chatbots are typically

designed for efficient and effective interactions, accentuating pragmatic quality, and there is a need to understand how to make these more pleasant and engaging. To further explore user perceptions of the interaction designs, the study in the same paper (Kathleen et al 2022) also included semi-structured interviews. We utilize the above mentioned literature in our proposed framework and its subsequent development.

3. Scope of the Geospatial Chatbot (Conversational Agents)

National Remote Sensing Centre (NRSC) is one of the primary centres of Indian Space Research Organisation (ISRO), Department of Space (DOS). It has the mandate for establishment of ground stations for receiving satellite data, generation of data products, dissemination to the users, development of techniques for remote sensing applications including disaster management support, geospatial services for good governance and capacity building for professionals, faculty and students. It is prudent for us to have a Geospatial Chatbot, and in this section we present the scope of the Geospatial Chatbot in a structured way that covers a wide range of topics related to geospatial data, including:

- *Waterspread of Reservoirs*: i) Real-time or near-real-time monitoring of reservoir waterspread ii) Historical trends in waterspread changes iii) Analysis of factors affecting waterspread, such as rainfall, evaporation, and human activities
- *Agriculture*: i) Crop health monitoring and identification of potential problems ii) Precision agriculture recommendations based on location, soil type, and crop type iii) Land use planning and analysis of agricultural productivity
- *Watershed*: i) Watershed delineation and characterization ii) Assessment of watershed health and identification of potential threats iii) Development of watershed management plans
- *Built-up Area*: i) Mapping and analysis of urban land use patterns ii) Assessment of urban growth and change iii) Identification of areas with potential for redevelopment or green space.

The specific scope of the Geospatial Chatbot will depend on the needs of the target users. For example, a chatbot designed for farmers would focus on agricultural data, while a chatbot designed for urban planners would focus on data related to land use and infrastructure. In addition to these core topics, the Geospatial Chatbot could also cover a variety of other geospatial data, such as: Local Recommendations, Navigation Assistance, Historical Points of Interest, Public Services Information, Multilingual Support, Disaster Management.

4. The Proposed Framework

Creating a geospatial chatbot involves integrating location-based services and data into a conversational interface. The primary purpose of the geospatial chatbot in India is to empower users with accurate and localized information, bridging the gap between various regions and their specific needs. We now present the proposed framework to build our robust geospatial chatbot.

4.1 Define the Purpose and Audience:

Purpose: Determine the primary goal of the geospatial chatbot (e.g., waterspread of reservoirs, agriculture, watershed, built up area etc., weather updates, providing local recommendations, navigation assistance, etc.).

Audience: Identify the target audience and their specific needs (e.g., travelers, tourists, hikers, city residents).

4.2 Choose the Right Platform and Tools:

Chatbot Platform: Choose a platform like Dialogflow, Microsoft Bot Framework, or Rasa for building the chatbot.

Mapping and Geolocation APIs: Integrate APIs like Google Maps, Mapbox, or OpenStreetMap for mapping and geolocation services.

Natural Language Processing (NLP): Implement NLP libraries or services like SpaCy or NLTK for processing user queries.

4.3 Design Conversational Flows:

Greetings and Introductions: Create a friendly welcome message and introduction to guide users on what the chatbot can do.

User Queries: Design conversation flows for common queries related to geospatial information, such as location-based recommendations, directions, nearby places, etc.

Error Handling: Plan for handling errors gracefully. If the bot doesn't understand a query, provide polite error messages and suggest alternative phrasings.

4.4 Implement Geospatial Capabilities:

Geocoding: Implement geocoding to convert addresses into geographic coordinates (latitude and longitude) and vice versa.

Reverse Geocoding: Allow users to get location information based on coordinates.

Routing and Directions: Integrate APIs for providing directions, routes, and estimated travel time between locations.

Points of Interest: Include data about local points of interest, restaurants, hotels, parks, etc., to provide relevant recommendations.

4.5 Ensure Data Privacy and Security:

User Privacy: Clearly communicate the chatbot's privacy policy regarding user data and location information.

Secure Communication: Use encryption protocols to ensure secure communication between the user and the chatbot server.

4.6 Optimize for Mobile Devices:

Responsive Design: Ensure the chatbot interface is responsive and works well on various devices, especially smartphones.

Location Services: Utilize mobile device location services for more accurate location information if users grant permission.

4.7 Test Extensively:

User Testing: Conduct extensive user testing to identify common user queries and refine the chatbot's responses.

Beta Testing: Release a beta version to a limited audience and gather feedback for further improvements.

4.8 Continuous Improvement:

Analytics: Implement analytics to track user interactions, popular queries, and user satisfaction.

Feedback Loop: Encourage users to provide feedback within the chatbot interface to continually enhance its performance and user experience.

Iterative Development: Regularly update the chatbot based on user feedback and changing user needs.

4.9 Compliance and Regulations:

Accessibility: Ensure the chatbot is accessible to users with disabilities, following accessibility guidelines.

Compliance: Adhere to relevant regulations and data protection laws concerning geolocation data and user privacy.

4.10 Documentation and Support:

User Guides: Provide clear documentation and user guides to help users understand the chatbot's capabilities and functionalities.

Customer Support: Offer user support channels to address issues, feedback, and inquiries promptly.

By following this framework, we created a geospatial chatbot that effectively assists users with location-based information while providing a seamless and engaging conversational experience.

5. Technology Stack for geospatial Chatbot

When developing a geospatial chatbot tailored for India, it's essential to choose a technology stack that not only provides robust geospatial capabilities but also accommodates the country's linguistic diversity, varying infrastructures, and unique regional needs. We use the following technology stack for our geospatial chatbot in the Indian context:

5.1 Natural Language Processing (NLP) and Conversational AI:

Dialogflow: Google's Dialogflow offers strong NLP capabilities and supports multiple Indian languages, making it ideal for understanding diverse user queries with the possibilities to include audio queries capabilities also.

Rasa: Rasa is an open-source conversational AI platform that allows for customized language models, essential for handling multilingual conversations in India.

5.2 Mapping and Geolocation APIs:

Google Maps API: Google Maps provides extensive mapping and geolocation services, covering a wide range of locations in India. It supports navigation, geocoding, and points of interest data. It may use the data from Google Earth Engine with satellite data (Sentinel, Indian satellites using BHUVAN, BHOONIDHI).

Mapbox: Mapbox offers customizable maps and geolocation services, allowing developers to create tailored maps for specific regions in India.

5.3 Multilingual Support:

Transliteration APIs: Utilize transliteration APIs like Google Transliterate to convert text from one script to another, enabling seamless communication in multiple Indian languages.

Indic Language APIs: Leverage Indic language APIs that support Indian scripts such as Devanagari, Tamil, Telugu, etc., ensuring accurate language processing and translation.

5.4 Cloud Services and Hosting:

Google Cloud Platform (GCP): GCP provides a robust infrastructure for hosting chatbot applications. It offers scalability, security, and various AI services that can enhance the chatbot's capabilities.

Amazon Web Services (AWS): AWS offers a wide array of cloud services suitable for hosting chatbots. It provides reliable hosting options and AI services for natural language processing.

5.5 Database and Geospatial Data Management:

PostgreSQL with PostGIS: PostgreSQL is a powerful open-source relational database, and PostGIS is an extension that adds support for geographic objects. It's ideal for managing geospatial data for various locations in India.

Firebase: Firebase Realtime Database is a NoSQL cloud-hosted database. It's suitable for real-time data synchronization and can handle location-based data efficiently.

5.6 User Interface and Frontend Development:

ReactJS: ReactJS is a popular JavaScript library for building interactive user interfaces. It provides a smooth user experience and allows developers to create responsive and dynamic frontend applications.

Material-UI: Material-UI is a React UI framework that provides ready-to-use components following the Material Design guidelines, ensuring a visually appealing and user-friendly interface.

5.7 Security and Data Privacy:

JSON Web Tokens (JWT): Use JWT for secure communication between the frontend and backend, ensuring data integrity and user authentication.

SSL/TLS Certificates: Implement SSL/TLS certificates to encrypt data transmission, ensuring user privacy and security during interactions.

5.8 Continuous Integration and Deployment:

Docker: Dockerize the chatbot application for containerization, ensuring consistency across different environments and facilitating easy deployment.

Jenkins: Jenkins is a popular open-source tool for continuous integration and continuous deployment (CI/CD), automating the build and deployment process.

By combining these technologies, we created a geospatial chatbot tailored for India that not only understands the diverse linguistic landscape but also provides accurate and context-aware location-based services, catering to the unique needs of users across the country.

6. Designing Geospatial Chatbot

Implementing geospatial capabilities for a chatbot involves integrating geolocation services, mapping APIs, and location-based data. To create a geospatial chatbot tailored for India, we followed these steps:

Step 1. Geocoding and Reverse Geocoding:

Choose a Geocoding Service: Use a reliable geocoding service like Google Maps Geocoding API or OpenCage Geocoding API. These services can convert addresses into geographic coordinates (latitude and longitude) which are essential for mapping.

Reverse Geocoding: Implement reverse geocoding to convert coordinates back into human-readable addresses. This functionality is crucial for providing location-specific information to users. Needless to say that here the Indian satellites using BHUVAN can also explore the fine granularity.

Step 2. Mapping and Geolocation APIs:

Google Maps API: Integrate Google Maps API to display interactive maps, provide directions, and show points of interest. Google Maps is widely used and provides extensive coverage in India.

Mapbox API: Mapbox offers customizable maps and extensive geolocation services. We can create custom maps tailored to specific regions in India and embed them into your chatbot interface.

Step 3. Points of Interest (POI) Data:

Utilize Local Data Sources: Collaborate with local businesses and government organizations to gather updated data on points of interest. This includes restaurants, hotels, tourist attractions, hospitals, and emergency services.

Third-party APIs: Leverage APIs like Zomato API for restaurants, TripAdvisor API for attractions, and OpenStreetMap data for various points of interest. These APIs can provide detailed and up-to-date information for Indian locations.

Step 4. Routing and Directions:

Calculate Routes: Implement routing algorithms to calculate the best routes between two locations. Consider factors like traffic conditions, modes of transportation (car, public transport), and real-time data to provide accurate directions.

Traffic Data: Integrate real-time traffic data into your routing system. Google Maps API provides traffic information for Indian cities, allowing users to avoid congested routes.

Step 5. Localized Language Support:

Multilingual Responses: Ensure that your chatbot can respond in multiple Indian languages. Implement language detection and translation services to provide responses in the user's preferred language.

Regional Dialects: Consider regional dialects and slangs specific to different Indian states to make conversations more relatable and natural for users.

Step 6. Emergency Services Integration:

Emergency Numbers: Provide emergency contact numbers for police, medical services, and fire departments in various Indian cities. Ensure this information is up-to-date and accessible in case of emergencies.

Step 7. User Permission and Privacy:

Request User Permission: Obtain user consent before accessing their geolocation data. Clearly explain to user, why we need this information and how it will be used.

Data Encryption: Encrypt user geolocation data during transmission and storage to protect user privacy and comply with data protection regulations.

Step 8. Continuous Data Updates:

Regular Data Feeds: Establish connections with reliable data sources to receive regular updates on geospatial data, such as new businesses, road constructions, or closed establishments. Keeping the data up-to-date is essential for accurate recommendations and directions.

Step 9. User Guidance and Error Handling:

Error Messages: Design user-friendly error messages for cases where the chatbot doesn't understand the location or the user's query. Provide suggestions on how the user can rephrase the question or specify the location.

7. Development and Implementation

In this section, we present the development and implementation activities of our geospatial chatbot which is currently operational on Water-spread for all Indian reservoirs,, and Urban Sprawl Gepspatial layers. It can be extended for other layers such as Forest cover, snow etc. The chatbot works in both text and audio modes and enables users to ask their query in their own regional language. The query is processed using the concepts of NLP, LLM, spatial data and in near real time. The output is also produced in the same regional language. Moreover, the result is displayed using bar graphs for better understanding. Time lapse with various images is shown for change detection. The chatbot works on the concept of unified pipeline with conversational agents which diverts the user query to the specified work engine.

Use case of Water reservoirs:

It performs advanced query processing using the Natural Language Processing (NLP) technique to detect the reservoir name from the given user query. In NLP, it uses the NLTK (Natural Language Toolkit) functionalities like word_tokenize and pos_tag to tokenize words from the query and extract specific nouns using a personalized filtering technique that excludes stop words, question words, cardinal numbers, and dates from the tokenized words respectively. Furthermore, it even uses a sequence matcher technique to find the closest matched reservoir name for the wrongly spelled or typed reservoir name.

The date extraction algorithm tries to extract dates from the user query, attempting to extract the start and end dates at each stage. If no results are obtained, the program advances to the next phase as follows:

- Directly extracting the date pattern, for queries like ‘till date’, ‘till today’ etc..
- Extracting the year patterns to handle queries with only one year mentioned, like ‘for this year’, ‘for last two years’ etc..
- Apply regular extraction to handle queries containing previous, etc., for a time span like weeks, months, or years.
- Enable query formats with ‘till’ for processing the query from the start date of the dataset.
- Using the stanza ‘en’ library to get any date format adjacent to the words like ‘to’ and ‘and’.

Following the aforementioned procedures, the region of interest (ROI) for the requested reservoir is retrieved from Google Earth Engine. Subsequently, the ROI is utilised to begin gathering image data, and a filter function is employed to eliminate partially covered satellite images of the reservoir from the collection. It will eliminate the "speckle" from the filtered-out photographs by finding the median value of each pixel based on the median value of the surrounding pixels, which is "25 metres". It will apply a binary mask with a threshold value of "-15" to the removed speckle image collection data in order to classify the water pixels in the satellite image. Next, it will separate the images with the lowest and highest number of water pixels. Finally, it will use the water spread calculation module, which consists of the computation of a binary mask. To do this, it sums up all the water pixels from the binary mask in kilometres or metres of that reservoir based on its area. Finally, it will display the map with the maximum water spread image.

After the calculations, a chart is generated consisting of the water spread of all the satellite images with their corresponding

dates in JSON format. This JSON format is converted to a bar plot using Chart.js in the frontend.

Moreover, it creates a time lapse in that the raster image collection data for a particular reservoir with the date range is divided into chunks, in which each chunk consists of 50 images. These chunks are partially processed to create the time lapse for each chunk with the respected URL link for each chunk. This time lapse is displayed recursively in the frontend.

By carefully implementing these geospatial capabilities, our chatbot offers accurate, localized, and reliable information to users across various locations in India, enhancing their overall experience and providing valuable assistance based on their geographic context. Figure 1 shows the basic sequence of activities in the form of block diagram.

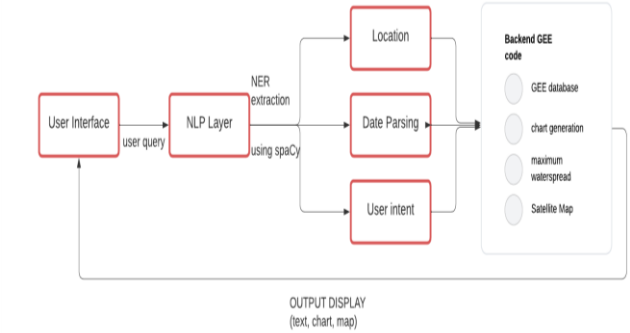

Fig. 1. Block diagram of Geospatial chatbot

This Geospatial chatbot not only helps the common man but more importantly helps the decision makers by providing very efficiently accurate near real time spatial data analysis.

8. Privacy and Security

This geospatial chatbot prioritizes user privacy and security by implementing several key measures:

Transparency and User Consent: Clearly communicate data collection practices, obtain explicit user consent for geolocation data access, and provide a transparent privacy policy.

Data Security: Utilize HTTPS encryption for secure data transmission, minimize geolocation data storage, and implement robust data encryption at rest.

Access Control: Implement strong authentication mechanisms, utilize access control lists, and restrict access to sensitive data within the chatbot and its administrative interfaces.

Third-Party Integration: Carefully vet third-party services and APIs, ensuring they adhere to data protection regulations.

Security Audits and Testing: Conduct regular security audits and penetration testing to proactively identify and address vulnerabilities.

Legal Compliance: Ensure strict adherence to Indian data protection laws, such as the Personal Data Protection Bill.

Incident Response: Develop a comprehensive incident response plan to effectively handle data breaches or security incidents.

By implementing these comprehensive security measures, our geospatial chatbot aims to build user trust, ensure compliance with Indian regulations, and maintain a secure and reliable environment for all users.

9. Optimize for User Experience

This geospatial chatbot aims to provide an optimized user experience for Indian users by focusing on several key areas:

Multilingual Support: Supports major Indian languages with accurate language detection and culturally appropriate responses.

Intuitive Conversations: Enables contextual understanding, provides user guidance, and offers smart suggestions for efficient interactions.

Personalized Experience: Allows users to set preferences, provides personalized recommendations, and leverages user history.

Accurate Geospatial Information: Ensures up-to-date and accurate geospatial data, utilizes geolocation effectively, and provides location-specific recommendations.

Cultural Sensitivity: Incorporates cultural nuances, regional relevance, and avoids culturally insensitive language.

User Feedback & Accessibility: Includes a feedback mechanism, prioritizes accessibility for users with disabilities, and provides offline support.

Performance Optimization: Ensures fast response times and high server uptime for a seamless user experience.

By implementing these strategies and continuously gathering user feedback, our chatbot aims to provide a user-friendly, culturally sensitive, and highly effective experience for the diverse Indian user base.

10. RESULTS AND DISCUSSION

The results obtained by GeoSpatial Chatbot using conversational agents, Generative AI, LLM, NLP etc. are very encouraging. It was able to dynamically process the geospatial query in near real time and present the output for various user queries, in regional languages, both using audio and text with graphical representations. The system uses a unified framework to cater to different thematic layers. Rich user interface is provided with Help & Guide at various levels for ease of use.

It proves to be a very efficient and effective tool for common man as well as for decision makers.

Figure 2 displays the working of water-spread application.

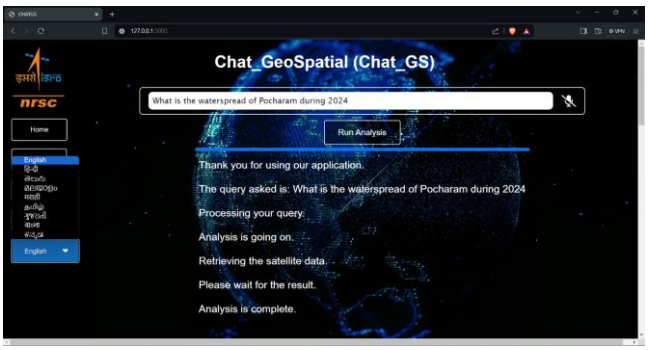

Fig. 2. Real-time processing steps

Figures 3, 4, and 5 displays the analysis and result generated for the user query asked in Figure 2. The map visualization shows the reservoir on the global map for the user to visualize its surroundings and location details. Moreover, the visualisation map also contain various geospatial data analysis tools like

zoom options, drawing shapes, pointing to a location, searching for a place, etc. Furthermore, the application generates time lapse for the reservoir using spatial images during the queried period. The conclusion plot presents water-spread values for each image. It also explicitly extracts the dates for the maximum and minimum water spread with values, providing useful insights for decision makers.

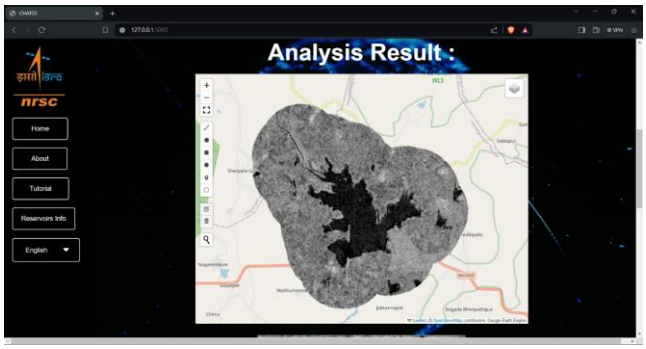

Fig. 3. Map visualization of reservoir with various tools for user

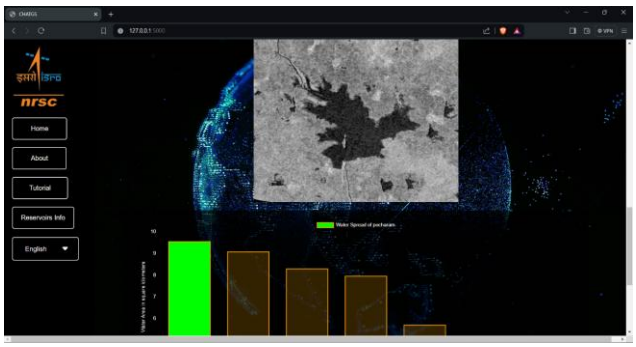

Fig. 4. Exhibiting the time lapse of satellite images for asked reservoir.

Fig. 5. : Conclusion plot displaying waterspread values (max & min in colors) of the reservoir, in text and audio.

11. Concluding Remarks and Future Scope:

In the rapidly evolving landscape of technology and user interactions, geospatial Conversational Agents have emerged as invaluable tools for enhancing user experiences in India. Key areas of future exploration include:

Enhanced User Interactions: Integration with augmented reality (AR) and multimodal interfaces (voice, gestures, visuals) will create more immersive and intuitive user experiences.

Smart City Integration: Seamless integration with IoT devices, sensors, and municipal systems will provide real-time information on traffic, transportation, and city services.

Disaster Management: Geospatial Conversational Agents will play a crucial role in disaster preparedness and response by providing real-time updates and emergency information.

Data Security and Ethics: A strong focus on data security, user privacy, and ethical considerations will be crucial for the responsible development of these technologies.

Collaborative Ecosystems: Fostering collaborations with businesses, government agencies, and NGOs will create a comprehensive ecosystem that benefits both users and service providers.

By embracing innovation, prioritizing user needs, and fostering a collaborative ecosystem, geospatial Conversational Agents have the potential to significantly impact India, improving access to information, enhancing community connectivity, and driving progress across the nation. The future of geospatial Conversational Agents in India is dynamic and promising, characterized by continuous innovation, user-centric design, and a commitment to enriching the lives of millions. By embracing emerging technologies, nurturing collaborations, and staying attuned to the evolving needs of the society, geospatial Conversational Agents or Chatbots are poised to redefine user experiences in unprecedented ways, paving the path for a connected, informed, and empowered India.

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