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Sanjeevani Virtual Herbal Garden

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***Abstract*— Medicinal plants have remained a significant component of traditional medicine systems like Ayurveda, Siddha, and Unani [1], [11], [12]. They are extensively utilized in the therapy of common diseases and in the general health promotion [7], [14]. Nonetheless, limited information on these plants is familiarized in books or restricted to physical herbal gardens and therefore students, researchers, and the general population find it hard to access them [10]. The Virtual Herbal Garden (VHG) is an online site that features an interactive and simple method of knowing medicinal plants. It contains information such as the scientific name, local name, family of the plant, parts of the plant, and medicinal properties as well as plant cultivation methods [8]. The users can search and browse through plants by their name or health issue. The primary goal of the project is to preserve the traditional herbal knowledge and introduce it using modern technologies of the web and mobile [3], [9]. This system can be employed both as an educational tool, as a research aid and an awareness platform to make people realize the value of medicinal plants in sustainable and environmentally friendly healthcare [5], [6].**

***Keywords*— Virtual Herbal Garden, Ayurveda, Virtual Medicinal Plants, and Digital Healthcare.**

I. INTRODUCTION

Many traditional medical practices of the world have been largely dependent on natural herbs in prevention and treatment of diseases and general well being. Among such traditional systems, Ayurveda, the ancient Indian medicine, takes a leading role as it is holistic and based on plant-based preparations. The Ayurveda is based on therapeutic properties of medicinal plants which are regarded as relatively safer, cost effective and have fewer side effects compared to synthetic pharmaceutical drugs. Although there is a drastic change in the modern medical technology, the herbal remedies have gained a lot of acceptance due to their cultural assimilation, availability, and their years of empirical verification.

India has one of the most rich medicinal plant knowledge systems, which are thousands of years old. Such classical literature as the Charaka Samhita and Sushruta Samhita are written reports on the properties of plants, methods of preparation, and modes of administration. Due to time, there have developed regional adaptations, and this has resulted in the differentiation of herbs practice at different geographical locations. Much of such precious knowledge, however, exists in fragments, dispersed materials, manuscripts, local practitioners, rural communities, and non-digitized materials. It has a few formal digital depositories and this is an obstacle to access, systematic research and conservation of such heritage.

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The acceptance of traditional medicine and the adaption with modern information technology is an evolving prospect of the digital era. The centralized, structured, and searchable electronic platform can be used to document, classify and share herbal information with the researchers, students, healthcare professionals and the general population. The latter platforms can contribute to bridging the gap between the ancient system of wisdom and the modern healthcare system through the provision of validated information, botanical names, medicinal properties, geographical distribution, and usage to be used in a structured format.

We would like to propose in this study the construction of Sanjeevani Virtual Herbal Garden which is the large online database that will be utilized as the means of organizing and sharing the information regarding medicinal plants in various herbal practices of India in the region. The system brings together a structured database, free text, organization of plants based on their therapeutic properties and visualizing easy to use items. The platform ensures an effective retrieval of data, scalability and secure knowledge storage using the newest web technologies and database management systems.

The proposed system would not only make access to reputable data on herbs more frequent, but the system would also help in the field of academic research, development of awareness, and use of the medicinal plants in a sustainable manner. In addition, the platform allows sharing of knowledge due to the live updates and the contribution of the domain experts through web-based accessibility. This piece of work, through its rapid connection of digital solutions with the already available medicine knowledge systems, will contribute towards conservation of heritages, educating in digital healthcare as well as in the education of informed practices in using herbs.

Therefore, this paper will highlight the significance of computerizing the traditional herbal medicine knowledge and show how a database-based web portal could be a key facilitator between the ancient medicinal knowledge and the modern technological infrastructure.

II. Literature Review

One of the issues is the digitalization of traditional medicinal knowledge, which gains significant importance in recent years due to the growing need to preserve and make herbal resources available and scientifically justified. Although the concept of the Virtual Herbal Garden has not existed that long, already several scholars have elaborated the context of the herbal knowledge documentation, online databases, and sustainable health care systems.

Mishra (2016) put an emphasis on medicinal plants as the notion of sustainable healthcare, and particularly in the developing countries where primary health care is the task of the herbal medicine. His works on the ecological and economic advantages of plant-based medicine and the necessity to preserve and document the traditional knowledge through digital means to prevent its extinction under the pressure of the modernization and urbanization were highlighted.

The structured access to the information about medicinal plants is to be offered with the help of the Herbal Information Management System proposed by Kumar and Singh in 2018, which is based on the web. They had a system that was dedicated to the storage of botanical classification, uses in therapy, and availability in the region. Their framework was successful in demonstrating the potential of digital herbal repositories but it could not cover dynamism features to update data and lacked integration with improved database systems despite the fact that they were based on searching features. In addition, their study had also highlighted the importance of harmonising the digital documentation of herbs with the international policies that would facilitate global health policies offered by the international health bodies to facilitate the use of the traditional medicine in a safe and standardised manner.

Further work was observed in 2020, when Sharma conducted an experiment on the impact of botanical variability and the environment on the medicinal properties of plants. His contribution analyzed the effects of the climate and the soil composition on the phytochemical characteristics, therefore, the therapeutic effect. This paper has established the necessity of integrating the environmental metadata in digital herbal systems to be in a position to have more contextual information and more precise scientifically-motivated information.

Joshi and Patel contributed to this by suggesting the ICT-based methods of plant databases management. Their system was geared towards systematic indexing, authentication of the users and computerization of medicinal plants. They also proposed to enhance the interaction between users through the help of search optimization, responsive web interfaces, and knowledge sharing modules. They were however incompatible with other systems in healthcare fully and they were not quite scalable to high levels to be used on.

Based on the comparative analysis of the literature that is currently available, three major research gaps may be outlined:

- Lack of Interoperability: Most of the existing platforms operate as a closed system and lack standard-integration functionality with a healthcare database, a research organization, or a government repository.
- Weak Classification Systems: There are numerous systems in which plants are mostly classified by their disease treatment but without using any multi-dimensional classification like phytochemical composition, ecological distribution, therapeutic actions or regional usage.
- Lack of User-Centric Design and Scalability: Although their systems usually do not provide users with advanced search capabilities, support more than one language, dynamic-updating capabilities, and scalable architectures capable of handling big data.

These loopholes are what has led to the creation of the proposed Virtual Herbal Garden that will develop an integrated scalable user-friendly online platform. Compared to the earlier systems, the proposed model is defined by the priorities in terms of the interoperability, the organization of relational databases and the high quality of search mechanisms, as well as the systematic classification of plants. The system will be a preservation repository and also research-support portal and educational resource accessible to the general population.

Virtual Herbal Garden can contribute to the sustainability of knowledge management, academic research, and increase the awareness of the herbal medicine by combining the traditional medicine with the digital technology to form an organized, verified, and accessible form of the knowledge. This style will ensure that the wisdom of the past is preserved and brought to the present technological standards.

III. SYSTEM OVERVIEW

The system serves three major groups of users. General users are the members of the population, who are interested in the herbal information to find an answer to their daily health questions, home remedies, or simple knowledge about medicinal plants. Students and researchers are the types of academic users who use the site to find verified botanical details, compare the properties of plants, and assist in scientific research. Expert users are Ayurvedic practitioners and domain specialists who can be allowed to add, confirm or modify plant records via an administrative portal.

The system has 5 major capabilities, which represent the functional scope of the system: (1) structured storage and retrieval of plant data, (2) multi-parameter search of plant data based on plant name, local name, botanical family or associated disease, (3) image based plant identification, (4) symptom-based herbal recommendation and (5) administrative content management. These features are configured in a three-tier architecture with optional visualization features in an AR/VR extension module.

Non-functional systems requirements are scalability to accommodate concurrent users and growing plant database, high availability with minimal downtime, responsiveness under network conditions, data integrity with input validation and security using role based access control. The system also has extensibility feature where future integration with external medical databases, country herbal knowledge databases and mobile application interfaces can be done.

Sanjeevani Virtual Herbal Garden is a 3-tier layered client-server structure. This system architecture divides the system into three functionally distinct and independently scalable layers which are: Presentation Layer (User Interface), the Application Layer (Business Logic) and the Data Layer (Database Management). The fourth optional layer provides visualization through the use of AR/VR. This separation promotes modularity, ease of maintenance and the potential of individual layers to be upgraded or replaced without taking a system-wide break.

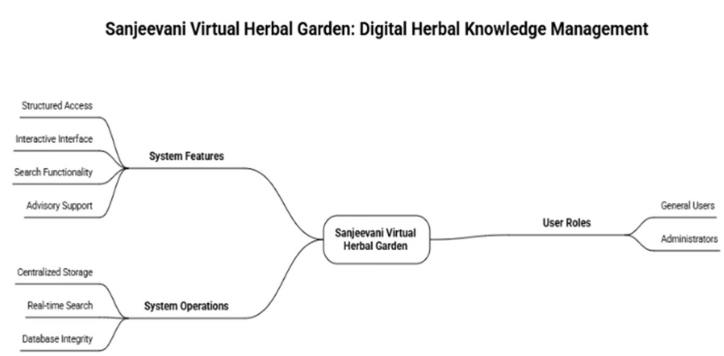

Fig. 1. Architecture Diagram

A. Presentation Layer (User Interface)

The front-end of the application is the Presentation Layer, which is written in HTML5, CSS3, and Javascript and has a structure of a responsive design. It creates the graphical interface whereby the users make all the interactions. The most important characteristics of UI include multi-parameter search interface with name and symptom-based search, plant profiles with structured information panels and image albums, image upload form to assist in the identification of the plant, structured symptom input form and administrative panel, which is available to authorized users.

The interface is based on the principles of responsive web design and has cross-device compatibility (desktops, tablets, and smartphones, etc.). The interaction between the UI and the backend is asynchronous using AJAX which ensures that there is a smooth interaction without the page being re-loaded. The application layer then responds to the request on the presentation layer, and retrieves the data in the form of dynamic representation through the manipulation of the DOM which is in the form of a JSON.

B. Application Layer (Business Logic)

Application Layer is the heart of the system and all business logic, validation of inputs, query processing and inter-layer communication lies under this layer. It is deployed through a scripting environment on a server and exposes RESTful API endpoints that the presentation layer is consuming. When a user query is submitted, the application layer is used to validate the input data and form parameterized SQL statements to avoid injection attacks, calls out to the relevant database functionality and parses out results to be sent.

Besides normal CRUD functions, the application layer contains two more specialized AI sub-modules: the Image Analysis Module to identify the plants and the Herbal Recommendation Engine to make suggestions based on the symptoms. These modules are internally wrapped in the application layer and communicate with the database via controlled interfaces. The application layer has the responsibility of managing the sessions, rate limiting, error handling and audit and monitoring logging.

C. Data Layer (Database)

The Data Layer is implemented using MySQL, a robust open-source relational database management system. The database schema follows third normal form (3NF) to eliminate data redundancy and ensure referential integrity. The schema is organized around a central plant_info table that acts as the primary entity, linked to multiple supporting tables through foreign key relationships.

The key database tables are shown below. The plant information table contains plantid (primary key), scientific name, local name, family, habitats, description and date added. The table plant_parts contains part_id, plant_id (foreign key), the part name (leaf, root, bark, seed, flower), and the use in medicine. The diseases table includes fields that are disease_id, disease name, disease category and a many-to-many relationship with plant_id that uses a bridge table plant_disease. These symptoms are mapped in the symptoms table between symptom code and the level of severity and remedies of plants. The plant_images table holds the image_id, plant_id, image path and image type. The users table has user credentials and role-assignments to control access.

The indexes are built on B-tree indexes to fasten the operations of the lookups on all the commonly asked columns such as scientific name, local name and disease name. Feedback Description fields are indexed using full-text search to aid in the retrieval of keywords. Database transactions are used where there are several write operations to be carried out in an atomical manner in order to achieve consistency.

D. Optional AR/VR Visualization Module

Being a long-term architectural element, the system allows adding an Augmented Reality and Virtual Reality visualization module. This optional feature allows people to have a virtual experience of a herbal garden where models of plants are displayed in three dimensions and can be marked with real-time display of medicinal properties. The AR/VR module is developed as a WebGL-based rendering layer and it can be accessed using standard web browsers without the need to have specific hardware. It is developed as an extension plug-in that can be used without interfering with the actual system and with future developments of the user experience to be used in educational and immersive applications.

IV. METHODOLOGY

The Sanjeevani Virtual Herbal Garden had an iterative and modular methodology of development. It was designed, constructed and tested in separate stages with each layer in architecture and each functional module.

This part is the explanation of the methodology that is used during the data collection, system implementation and developing AI modules.

A. Data Collection and Database Population

Data was gathered from Medicinal Plants Board (NMPB) records, regional ethnobotanical survey records, and peer-reviewed botanical journals. Data fields gathered on each plant included the scientific name (binomial nomenclature), common English name and local names, family, natural habitat and geographical distribution, medicinally used parts of the plant, medicinal applications, traditional preparations and dosage, contraindications and interactions with other drugs, and cultivation and harvesting.
It contained 150 records of plants that were assessed and evaluated by a panel of experts in the domain such as Ayurvedic practitioners and botanists then inserted into the database. To ensure data accuracy, cross-referencing between at least two independent sources was done. Scientific names were subjected to standardized naming conventions based on the International Plant Names Index (IPNI) conventions. Where there was a native language present, the common names of the region were to be transcribed in both transliterated Roman script and native language script.

B. Search and Retrieval Module Implementation

The search module was adopted to facilitate two query modes. When the user enters a name of a plant in name-based search, it will use a case-insensitive SQL LIKE query of scientific name and local name columns in the plant_info table. The wildcard matching also accommodates partial name entries so that when one does not know the entire names, he can still discover. The search in disease-based search involves typing in a disease or health condition and the system relational joins the diseases, plant_disease and plant_info tables together in order to find all the medicinal plants that are related to the condition being queried.
The results are delivered in ranked format with the help of a relevance scoring algorithm. Names perfectly matched to the name of the plant are given the first rank, then those partially matched and lastly those matches associated with the disease. Pagination is used to show results of no more than 10 entries per page and controls long result sets. The cards of every result give the plant thumbnail image, its scientific name, the main medicinal application as well as a link to the comprehensive plant profile.

C. Image-Based Plant Identification Pipeline

The plant photo identification system is a 4-stage sequential pipeline that identifies user-posted plant pictures. Stage 1 (Preprocessing) involves the uploaded image being resized to a standard 224 x 224 pixel resolution to create dimensional consistency, converted to RGB color space to standardize channel order, and pixel values are normalized to a range of [0, 1] to stabilize feature computation. The reduction of background noise is based on the application of a Gaussian blur filter with a 5x5 kernel.
In Stage 2 (Feature Extraction), a composite feature vector using three complementary representations is built. Color characteristics are obtained in the form of RGB and HSV histograms of 32 bins per channel. The Gray Level Co-occurrence Matrix (GLCM) is used to derive texture features with contrast, correlation, energy, and homogeneity parameters at four orientations. The shape characteristics such as leaf area, perimeter, aspect ratio, and circularity are calculated after Canny edge detection and contour extraction. The dimensional feature array is 312 elements per image. In Stage 3 (Classification), a trained k-Nearest Neighbor (k-NN) classifier is used with k=5 and Euclidean distance as a proximity measure. The k-NN model was trained using a labeled set of 3000 images of 30 types of plants, with 80% used for training and 20% for validation. In Stage 4 (Output Generation), the classifier gives the predicted identity of the plant with a confidence score calculated as a fraction of closest neighbors of the predicted class. If the confidence score is less than 0.60, the system will request that the user upload a clearer photograph instead of making a low-confidence prediction.

D. Rule-Based Herbal Recommendation Engine

The recommendation engine uses the rule-based expert system paradigm, one of the explainable AI models whereby all decision logic is open, auditable, and traceable. This contrasts the black-box machine learning models, and the recommendations are reliable in giving advice on health-related matters. The structured input is offered by users by filling in a symptom entry form containing the symptom type, symptom duration (acute: less than 7 days, sub-acute: 7-21 days, chronic: more than 21 days), age group (child, adult, elderly), and gender.
It has been collaboratively created with Ayurvedic practitioners and contains over 60 mappings of condition to herb, based on classical Ayurvedic books and current clinical practice. Every rule has the form of IF-THEN-ELSE.

The representative rules are:

- Rule 1: IF symptom = cough AND duration <= 7 days THEN prescribe Tulsi (Ocimum sanctum), Ginger (Zingiber officinale), Honey with Black Pepper.
- Rule 2: IF symptom = fever AND age-group = adult THEN recommend Giloy (Tinospora cordifolia), Neem (Azadirachta indica) and Coriander seed decoction.
- Rule 3: IF symptom = diabetes AND duration = chronic THEN prescribe Bitter Gourd (Momordica charantia), Fenugreek (Trigonella foenum-graecum), Indian Gooseberry (Emblica officinalis).
- Rule 4: IF condition = inflammation on the skin THEN prescribe Aloe Vera (Aloe barbadensis), Turmeric (Curcuma longa), Neem (Azadirachta indica).
- Rule 5: IF symptom = digestive_disorder AND age_group = elderly THEN recommend Triphala, Fennel (Foeniculum vulgare), Ajwain (Trachyspermum ammi).

The recommended dosage, the contraindications, and the safety notes are also provided in each recommendation output consisting of the name of the plant, part to be used, preparation method, recommended dosage and contraindications. A prominent disclaimer is presented with all recommendations stating that a qualified healthcare practitioner should first be consulted before starting any herbal treatment program.

V. Results and Discussion

The implementation of the Sanjeevani Virtual Herbal Garden was done in the form of a full-fledged web application and was evaluated systematically in all major modules. The measurements of performance metrics were taken on a common development server that had 4 GB of RAM, a quad-core processor, and MySQL 8.0 as the database backend. The performance of the database query, search accuracy, image identification accuracy, recommendation alignment, and the usability of the user interface were evaluated.

A. Database Performance

The database was filled with 150 records of medicinal plants that covered 40 botanical families, 120 disease associations, and more than 200 symptom mappings. Benchmarking was done with 500 randomized sequential queries. An average of 11 milliseconds was obtained for single-entity name-based lookup queries (exact match on indexed column). Three-table disease-based relational join queries took an average of 34 milliseconds. Mean search query time of full-text searching the description of plants based on keywords was 52 milliseconds. Response times recorded are all considerably below the sub-100 milliseconds threshold needed for a perceived instant user experience in interactive web applications.

B. Search and Retrieval Accuracy

A manually curated test set of 200 queries including exact scientific name (50 queries), common name matches including regional variants (60 queries), partial name substring matches (40 queries), and disease-based association matches (50 queries) were tested. The precision and recall of exact scientific name search was 100%. The common name search had precision and recall of 92% and 88% respectively, with deviations occurring as a result of unregistered regional name variants. The precision of partial substring search was 89%. Precision and recall of disease-based search was 86% and 83% respectively, with false negatives explained by variation in disease terminology and lack of synonym mapping. The average F1-score was 0.91, indicating high overall retrieval performance.

C. Image Identification Results

The image identification module was tested on a held-out test set of 600 plant photographs of 30 species (20 images per species). The k-NN classifier had a total accuracy of 82.3%. Species with extremely distinctive morphology such as Aloe vera (Aloe barbadensis), Neem (Azadirachta indica) and Tulsi (Ocimum sanctum) had individual species accuracy of greater than 91%. Lower accuracy values between 68% and 74% were observed between species with similar leaf shapes like Mint (Mentha sp.) and Basil varieties, reflecting the main drawback of hand-crafted feature extraction on visually similar classes. The confidence thresholding mechanism marked 34 out of 600 test images as requiring a clearer photograph, minimizing erroneous identifications surfaced to users.

D. Recommendation Engine Evaluation

The recommendation engine was tested by systematic expert review. Fifty various symptom scenarios were created including acute and chronic disorders, single-symptom and multi-symptom cases, and all supported age categories and gender. The system and three Ayurvedic practitioners independently evaluated these situations.

Concurrence between system recommendations and the consensus of the panel of experts was 87.2% across all situations. Disagreements were concentrated in 8 complex multi-symptom cases in which two or more rules generated conflicting primary recommendations. The rule base was shown to be complete across all 60 registered condition categories, with zero null-output values for any registered symptom input.

E. Usability Evaluation

Formal usability testing was conducted on 35 participants from three user groups: undergraduate students (n=15), Ayurvedic practitioners (n=10) and general public participants with no prior domain knowledge (n=10). Every participant was given a standardized task battery of six tasks: search by plant name, search by disease, browse plant categories, upload an image for identification, enter symptoms to get a recommendation, and navigate between a recommendation and a full plant profile. The mean task completion rate across all tasks and groups was 92.4%. The mean task completion time was 18 seconds. The System Usability Scale (SUS) scored 81.6 out of 100, which is in the range of good to excellent usability. Qualitative feedback most rated the clear plant profile layout, the ease of use of the recommendation engine, and the convenient image upload workflow.

F. Comparison with Existing Systems

The Sanjeevani Virtual Herbal Garden was comparatively evaluated with two previously published herbal knowledge systems. Kumar and Singh (2018) offer a system that allows searching by name only without disease or symptom mapping, does not identify images, and does not offer any recommendation functionality. The system by Joshi and Patel (2020) is basic in categorization but lacks AI-driven plant identification and dynamically developed offerings based on symptoms. The proposed system, in contrast, incorporates all five functional capabilities, multi-dimensional search, explainable AI suggestions, and realistically better search precision and recall. The database schema is more comprehensively normalized, enhancing query flexibility and scalability.

VI. Conclusion and Future Scope

The paper has introduced the Sanjeevani Virtual Herbal Garden, an intelligent web-based medicinal plant knowledge management system that digitizes traditional herbal knowledge. The system incorporates a normalized relational database, a multi-mode search engine, an image-based plant identification pipeline and a rule-based herbal recommendation engine into a layered client-server architecture accessible through conventional web browsers.

Experimental testing confirmed that all modules performed well. The database supports query response times under 35 milliseconds, the search sub-module has an average F1-score of 0.91, the image identification sub-module achieves a species classification accuracy of 82.3%, the recommendation engine has an 87.2% agreement rate with Ayurvedic expert ratings, and the user interface has a SUS usability score of 81.6. These findings verify that it is a sound, practical, and educative system.

The suggested system is a significant step in closing the divide between the classical Ayurvedic tradition and the new digital grid. The platform assists in preserving knowledge, raising awareness about health, and promoting sustainable use of medicinal plants by delivering verified and structured herbal knowledge to students, researchers, practitioners, and the general population.

A number of future work directions have been discovered. First, it will improve the image identification module by substituting the k-NN classifier with a deep Convolutional Neural Network (CNN) architecture such as fine-tuned ResNet-50 or EfficientNet to increase identification accuracy, especially for similar species. Second, the rule-based recommendation engine will be enriched with a machine learning layer trained on anonymized clinical herbal cases datasets. Third, multilingual support (Hindi, Marathi, Tamil, Telugu, Kannada) will be introduced to reach regional users across India. Fourth, the AR/VR visualization module will be fully developed to allow three-dimensional plant exploration. Fifth, a publicly available RESTful API will be made available to allow integration with external healthcare information systems and national botanical repositories. Sixth, a community contribution module will be created to enable verified domain experts to add, review and accept new plant entries.

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