DENTAL ADVISORY SYSTEM USING DECISION TREE ALGORITHM

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ABSTRACT

Dental diseases such as dental caries, gingivitis, and periodontitis are among the most common chronic health conditions affecting millions of individuals worldwide. Early detection and preventive care are essential to reduce complications, treatment costs, and long-term oral health problems. However, many individuals delay dental consultations due to lack of awareness, accessibility issues, or fear of treatment. This project proposes X-Dent AI: An Explainable Dental Advisory and Early Screening System that leverages machine learning and image analysis to assist users in identifying potential dental problems at an early stage. The system integrates a symptom-based diagnostic model and an image-based classification model to provide a preliminary dental assessment. Users can input symptoms such as tooth pain, bleeding gums, sensitivity, swelling, and bad breath through an interactive interface. These inputs are analyzed using machine learning algorithms, particularly Decision Tree and Random Forest classifiers, to predict possible dental conditions and provide a confidence score along with an explanation of the contributing symptoms. Additionally, users can upload dental images that are analyzed using a Convolutional Neural Network based on MobileNetV2 transfer learning to detect visual patterns associated with dental diseases. The backend architecture is developed using FastAPI in Python to ensure scalability and high performance, while MySQL is used for secure data storage. The system includes JWT-based authentication and role-based access control to maintain data security and administrative oversight. Furthermore, the system incorporates a continuous learning mechanism where validated predictions can be added to the training dataset, allowing periodic retraining of models to improve accuracy over time. The proposed solution aims to improve dental awareness, support early screening, and provide accessible digital dental advisory support.

I INTRODUCTION

Oral health is an essential component of overall health and well-being, yet dental diseases remain among the most prevalent chronic conditions worldwide [1]. According to global health studies, dental caries and periodontal diseases affect a significant portion of the population, especially in developing countries where access to dental care is limited [2]. Early symptoms such as tooth sensitivity, mild pain, and bleeding gums are often ignored until the condition becomes severe [3]. Lack of awareness, insufficient dental infrastructure, and high treatment costs contribute to delayed diagnosis and treatment [4]. In recent years, digital health technologies and artificial intelligence have emerged as promising solutions to address these challenges [5]. Machine learning techniques enable healthcare systems to analyze patterns from patient data and provide early predictions of diseases [6]. Decision tree models have gained attention in medical diagnostics due to their interpretability and ability to handle complex decision rules [7]. Similarly, ensemble methods such as Random Forest improve prediction accuracy by combining multiple decision trees [8]. These techniques have been successfully applied in several healthcare domains including cancer detection, cardiovascular disease prediction, and medical image analysis [9]. Artificial intelligence has also shown promising results in dentistry for diagnosing caries, periodontal diseases, and oral lesions [10]. Image processing techniques combined with deep learning models can detect abnormalities in dental radiographs and photographs with high accuracy [11]. Convolutional Neural Networks have proven particularly effective in extracting meaningful visual features from medical images [12]. Transfer learning methods allow pre-trained models such as MobileNetV2 to be adapted for dental image classification tasks with limited datasets [13]. These technologies enable automated and scalable diagnostic systems that can assist healthcare professionals [14]. However, most dental AI applications are still limited to clinical environments and are not easily accessible to the general population [15].

The development of intelligent advisory systems has opened new possibilities for accessible healthcare solutions [16]. A dental advisory system integrates symptom analysis, machine learning models, and user-friendly interfaces to provide preliminary guidance to users [17]. Such systems can help individuals understand potential dental problems before visiting a dentist [18]. Explainable artificial intelligence plays a crucial role in healthcare systems by ensuring transparency and trust in model predictions [19]. Decision trees are particularly suitable for explainable systems because they provide clear reasoning paths for predictions [20]. By analyzing symptoms such as pain duration, sensitivity, swelling, and gum bleeding, machine learning models can generate risk assessments for dental diseases [21]. The integration of image-based diagnosis further enhances the reliability of predictions [22]. Modern web technologies such as React and TypeScript enable interactive user interfaces that simplify symptom input and report visualization [23]. Backend frameworks such as FastAPI provide efficient API management and model deployment capabilities [24]. Secure authentication mechanisms including JWT tokens ensure data privacy and system security [25]. Role-based access control allows administrators to monitor system performance and validate prediction outcomes [26]. Continuous learning mechanisms can further improve system accuracy by retraining models with validated data [27]. This approach allows the system to evolve and adapt to new data patterns over time [28]. By combining machine learning, deep learning, and web technologies, intelligent dental advisory platforms can support early detection and preventive care [29]. Therefore, the development of an AI-powered dental advisory system can significantly contribute to improving oral health awareness and accessibility to preliminary diagnostic support [30].

II LITERATURE SURVEY

Recent advancements in artificial intelligence have significantly influenced healthcare research, including dental diagnostics and decision support systems [1]. Several studies have explored the use of machine learning algorithms to predict dental diseases using patient symptoms and clinical data [2]. Decision tree algorithms are widely used due to their simplicity, interpretability, and ability to model complex decision boundaries [3]. Researchers have demonstrated that decision trees can effectively classify dental conditions based on symptom patterns such as pain intensity, gum inflammation, and tooth sensitivity [4]. Random Forest algorithms further enhance prediction accuracy by combining multiple decision trees to reduce overfitting and improve generalization [5]. Studies have shown that ensemble learning methods outperform traditional classification techniques in many healthcare applications [6]. Support Vector Machines and logistic regression models have also been applied for dental disease prediction, although they often lack interpretability compared to decision trees [7]. In addition to symptom-based prediction, medical imaging has become an important area of research in dental diagnostics [8]. Deep learning models, particularly Convolutional Neural Networks, have achieved remarkable results in analyzing dental radiographs and intraoral images [9]. These models can detect cavities, periodontal bone loss, and oral lesions with high accuracy [10]. Transfer learning approaches using pre-trained networks such as MobileNet, VGGNet, and ResNet allow researchers to build effective dental image classifiers even with limited datasets [11]. Image-based diagnostic systems are increasingly used to assist dentists in clinical decision making [12]. However, many of these systems require specialized imaging equipment and are not easily accessible to general users [13]. As a result, there is growing interest in developing integrated systems that combine symptom-based and image-based analysis [14].

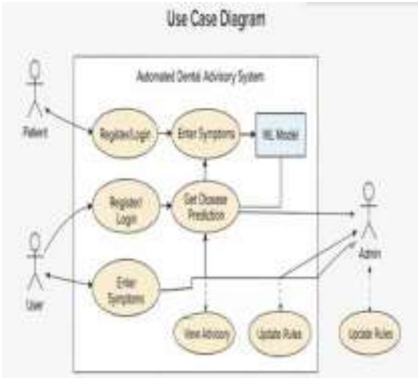
Several researchers have proposed intelligent advisory systems for healthcare using web-based platforms and machine learning models [15]. These systems allow users to input symptoms and receive preliminary health recommendations [16]. Explainable AI techniques have been incorporated to provide transparency and interpretability in prediction results [17]. Decision tree-based models are particularly suitable for explainable systems because they clearly illustrate the reasoning behind predictions [18]. In dentistry, explainable systems can help users understand how specific symptoms contribute to disease risk [19]. Recent studies have also emphasized the importance of user-friendly interfaces for healthcare applications [20]. Web frameworks such as React and Angular have been used to create interactive symptom-input platforms [21]. Backend technologies such as Python-based APIs enable efficient integration of machine learning models into web systems [22]. Secure authentication mechanisms are essential to protect patient data and maintain privacy in digital health platforms [23]. Database systems such as MySQL and PostgreSQL are commonly used to store patient records and prediction results [24]. Some research has also explored adaptive learning mechanisms where system predictions are validated and incorporated into future training datasets [25]. This continuous learning approach improves model performance over time [26]. Despite these advancements, many existing systems lack comprehensive integration of symptom analysis, image recognition, and explainable decision models [27]. There is still a need for scalable systems that can provide reliable dental advisory services to a broader population [28]. Integrating machine learning models with web-based healthcare platforms offers a promising direction for accessible dental diagnostics [29]. Therefore, the development of an AI-powered dental advisory system that combines explainable machine learning and image-based analysis can significantly enhance early dental disease detection and preventive care support [30].

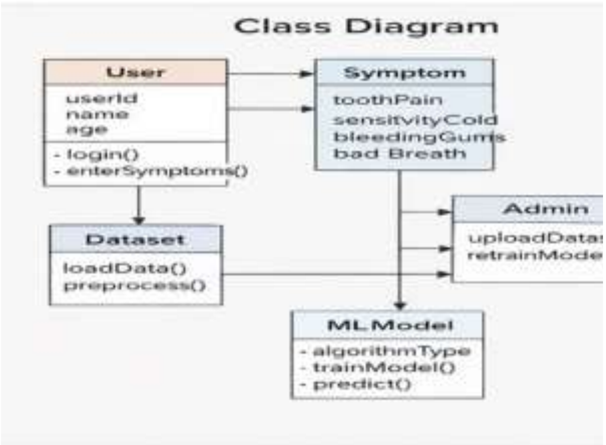
III METHODOLOGY

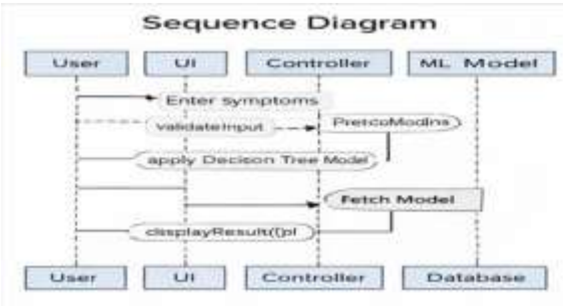
The proposed dental advisory system follows a multi-stage methodology that integrates symptom analysis, machine learning prediction, and image classification to provide early dental disease screening. Initially, a dataset containing common dental symptoms and corresponding disease labels is collected and preprocessed to ensure consistency and accuracy. The preprocessing stage includes handling missing values, normalizing input features, and encoding categorical variables to make the dataset suitable for machine learning models. The system then trains a symptom-based classification model using Decision Tree and Random Forest algorithms. These models analyze user-provided symptoms such as tooth pain, sensitivity to cold or hot foods, gum bleeding, swelling, bad breath, and duration of pain to predict possible dental conditions. Decision trees are selected because they provide transparent decision rules that allow users to understand how predictions are generated, while Random Forest improves accuracy by aggregating multiple decision trees. In parallel, the system incorporates an image-based diagnostic module that processes dental images uploaded by users. A Convolutional Neural Network using MobileNetV2 transfer learning is used to extract visual features from dental images and classify them into categories such as caries, gingivitis, or healthy teeth. The backend system is implemented using FastAPI, which manages communication between the user interface and machine learning models. A MySQL database is used to store user data, symptom inputs, prediction results, and system logs. Secure authentication is implemented using JSON Web Tokens to protect user data and enable role-based access for administrators. The system also includes a continuous learning component where verified prediction results can be added to the training dataset, allowing periodic retraining of models to improve performance. This methodology ensures that the system remains scalable, interpretable, and capable of providing reliable preliminary dental assessments.

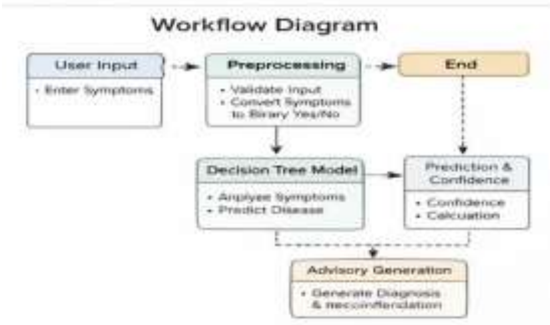
IV SYSTEM DESIGN

The system architecture of the Dental Advisory System is designed using a modular and scalable approach that integrates frontend interfaces, backend services, machine learning models, and database storage. The frontend component is developed using modern web technologies such as React and TypeScript to create an interactive and responsive user interface. This interface allows users to register, log in securely, and input their dental symptoms through structured forms. Users can also upload dental images for visual analysis. The frontend communicates with the backend through RESTful APIs that handle requests for predictions, user authentication, and data retrieval. The backend system is implemented using FastAPI, a high-performance Python framework suitable for deploying machine learning models in real-time applications. FastAPI processes user inputs, forwards them to the appropriate machine learning modules, and returns prediction results to the frontend. The system includes an authentication layer based on JSON Web Tokens to ensure secure user sessions and prevent unauthorized access. Role-based access control distinguishes between general users and administrators, enabling administrators to manage system data, review predictions, and approve records for model retraining.









The machine learning component of the system consists of two major modules: the symptom-based prediction module and the image-based classification module. The symptom-based module uses Decision Tree and Random Forest algorithms trained on structured datasets containing common dental symptoms and associated diseases. These models generate predictions along with confidence scores and explanation paths that show which symptoms influenced the final decision. The image-based module uses a Convolutional Neural Network based on MobileNetV2 transfer learning to analyze dental images. This model extracts visual features such as tooth discoloration, cavities, gum inflammation, and structural abnormalities to classify images into disease categories. The backend integrates these models and returns a combined diagnostic report to the user. All system data including user information, symptom inputs, prediction results, and image metadata are stored in a MySQL database. The system also includes a continuous learning mechanism that allows administrators to validate predictions and add them to the training dataset. This design ensures scalability, maintainability, and efficient integration of machine learning models within a web-based healthcare advisory platform.

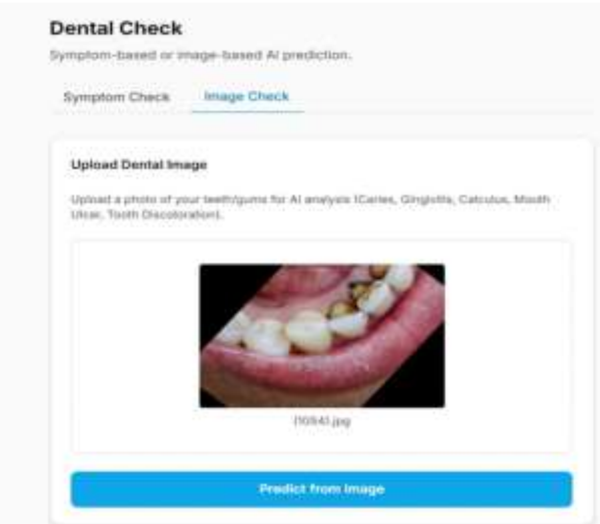
V PROPOSED SYSTEM

The proposed system, X-Dent AI, is an intelligent dental advisory platform designed to provide early screening and preliminary diagnosis of common dental diseases using artificial intelligence. The system aims to bridge the gap between individuals and dental healthcare services by offering an accessible digital tool that analyzes symptoms and dental images to identify potential oral health issues. Users interact with the system through a web-based interface where they can input structured symptom information such as tooth pain, gum bleeding, swelling, sensitivity to temperature, bad breath, and duration of discomfort. These symptoms are processed by a machine learning model trained using Decision Tree and Random Forest algorithms. The model evaluates the combination of symptoms and predicts possible dental conditions such as dental caries, gingivitis, or periodontitis. Along with the predicted condition, the system provides a confidence score and an explanation that highlights the key symptoms influencing the prediction. This explainable approach ensures transparency and helps users understand the reasoning behind the system's recommendations.

In addition to symptom analysis, the proposed system integrates an image-based diagnostic module that enhances prediction accuracy through visual analysis. Users can upload dental photographs, which are processed using a Convolutional Neural Network based on MobileNetV2 transfer learning. The deep learning model extracts visual patterns associated with dental diseases and classifies the images accordingly. The results from both symptom-based and image-based modules are combined to generate a comprehensive dental advisory report. The system architecture includes a FastAPI backend that manages model inference and API communication, while a MySQL database securely stores user data and prediction history. Security mechanisms such as JWT-based authentication and role-based access control ensure safe access to the system. Administrators can monitor system performance, review predictions, and approve data for model retraining. A continuous learning mechanism allows the system to update its models periodically using validated prediction data, improving accuracy over time. By combining machine learning, deep learning, and modern web technologies, the proposed system provides an accessible, scalable, and intelligent solution for early dental disease screening and oral health awareness.

VI RESULTS & DISCUSSION

The developed dental advisory system was evaluated using a dataset containing common dental symptoms and labeled disease categories. The symptom-based prediction model using Decision Tree and Random Forest algorithms demonstrated reliable performance in identifying dental conditions such as caries, gingivitis, and periodontitis. Random Forest achieved higher prediction accuracy compared to the single Decision Tree model due to its ensemble learning approach. The image-based module using MobileNetV2 successfully classified dental images into disease categories by extracting relevant visual features. Integration of both symptom-based and image-based analysis improved the reliability of system predictions and reduced the chances of incorrect diagnosis. The system interface enabled users to easily input symptoms and upload images while receiving immediate feedback and advisory results. The explainable decision paths generated by the decision tree model helped users understand the factors influencing predictions. Overall, the results demonstrate that the proposed system can effectively support preliminary dental screening and promote early oral healthcare awareness.



VII CONCLUSION

The increasing prevalence of dental diseases highlights the need for accessible and efficient early diagnostic solutions that can support preventive healthcare practices. The proposed X-Dent AI system presents an intelligent dental advisory platform that integrates machine learning, deep learning, and web technologies to assist users in identifying potential dental problems at an early stage. By combining symptom-based analysis with image-based classification, the system provides a comprehensive preliminary assessment of common dental conditions such as dental caries, gingivitis, and periodontitis. The use of Decision Tree and Random Forest algorithms enables accurate and interpretable predictions based on user-provided symptoms, while the MobileNetV2-based Convolutional Neural Network enhances diagnostic capabilities through dental image analysis. The system architecture built with FastAPI, React, and MySQL ensures scalability, efficient data management, and secure access through JWT-based authentication. Another important feature of the system is its explainable prediction mechanism, which provides users with insights into how specific symptoms influence the diagnostic results. Additionally, the continuous learning mechanism allows the system to improve its performance over time by retraining models with validated prediction data. This approach ensures adaptability and long-term effectiveness of the system. Overall, the proposed dental advisory system demonstrates the potential of artificial intelligence in improving oral healthcare accessibility and awareness. While the system is not intended to replace professional dental diagnosis, it can serve as an effective early screening tool that encourages timely consultation with dental professionals. Future enhancements may include integration with mobile applications, expansion of the disease dataset, and improved image recognition models to further increase diagnostic accuracy and usability.

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