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Implementation of Expert System Applications using Forward Chaining to Detected Dental Health

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Abstract

Dental diseases remain one of the most common health issues globally, often resulting from lack of early detection and limited access to dental specialists. This research presents the implementation of an expert system application that utilizes the Forward Chaining inference method to diagnose dental health conditions based on user-reported symptoms. The system integrates a knowledge base modeled from expert consultation with dentists, consisting of symptom sets and rule-based logic. Findings indicate that the Forward Chaining approach is effective for step-by-step rule evaluation, generating accurate diagnoses for diseases such as caries, gingivitis, periodontitis, halitosis, and pulpitis. The study demonstrates that expert systems can support preliminary dental screening and improve public awareness of dental health.

Keywords: *Expert System, Forward Chaining, Dental Health, Knowledge Base, Rule-Based System.*
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I. INTRODUCTION

Dental diseases affect millions of people worldwide and are often ignored due to limited knowledge or delayed consultation with dental professionals. Early detection is critical in preventing complications such as tooth decay, gum inflammation, and periodontal disease. However, not all individuals have immediate access to dentists. Artificial Intelligence, particularly Expert Systems, enables automated reasoning that mimics human experts in specific domains. By integrating a structured knowledge base and inference mechanism, an expert system can assist in preliminary diagnosis.

This research focuses on implementing an Expert System Application using Forward Chaining to detect dental health issues. Forward Chaining follows a data-driven approach, starting from known facts (symptoms) and moving forward to derive conclusions (diseases). This methodology suits scenarios in which users input symptoms and expect diagnostic results. Artificial intelligence, specifically through the application of expert systems[8], offers a promising avenue to augment diagnostic capabilities and improve accessibility. These systems are designed to replicate the decision-making process of a human expert by utilizing a structured knowledge base and a logical inference engine. This research investigates the development of a diagnostic tool based on a forward chaining methodology, a data-driven approach that reasons from known facts, such as patient symptoms, toward a logical conclusion. The primary objective of this study is to analyze the application and effectiveness of a forward chaining expert system for preliminary dental health detection. The system's architecture is centered on a rule-based knowledge base, derived from established dental literature and expert consultation, which is processed by a custom inference engine. This paper details the system's design, from knowledge acquisition and rule formulation to its implementation as an accessible web-based application. Furthermore, it presents a rigorous validation and quantitative performance evaluation to ascertain the system's diagnostic accuracy, thereby assessing its viability as a reliable preliminary screening tool.

II. THEORETICAL FRAMEWORK

2.1 Expert System

Expert systems are a prominent domain within artificial intelligence that aims to replicate the decision-making proficiency of a human expert in a specific field. The core architecture of these systems consists of a knowledge base, which stores domain-specific information and heuristics, and an inference engine that applies logical reasoning to this knowledge. The primary function is to address complex problems by processing this structured information, ultimately offering expert-level conclusions and advice to users who may not possess specialized knowledge in the area. An expert system is a computer program designed to emulate the decision-making ability of a human expert. It comprises three main components:

a. Knowledge Base
b. Inference Engine
c. User Interface

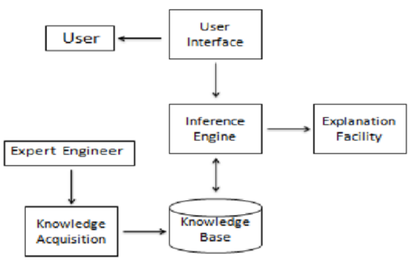

Figure 2.1 Expert System Flowchart

Based on figure 2.1 that grounded in the utilization of a rule-based knowledge base, which acts as the central repository for facts and rules pertaining to dental health diagnostics[6]. This

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knowledge is systematically encoded as a series of production rules, commonly expressed in an "IF-THEN" format[10]. For example, a rule could be structured as, "IF a patient presents with symptoms A and B, THEN diagnosis C is highly probable." This method allows for the explicit representation of expert knowledge, making it accessible for automated reasoning.

2.2 Forward Chaining

Forward Chaining is a data-driven inference technique in which reasoning begins with available facts. The system evaluates rules whose premises match the provided facts, then triggers conclusions.

Forward chaining searches from a problem to its solution, the picture can be seen in fgure 1.

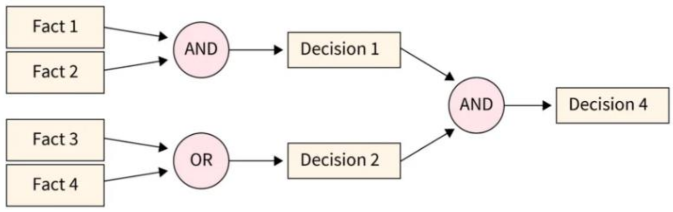

Figure 1. Foward Chaining

2.3 Dental Health Diagnosis

Common dental conditions include:

a. Dental Caries
b. Gingivitis
c. Periodontitis
d. Pulpitis
e. Halitosis
f. Tartar accumulation

Each disease has identifiable symptoms that can be modeled into the knowledge base.

This research is grounded in the utilization of a rule-based knowledge base, which acts as the central repository for facts and rules pertaining to dental health diagnostics[6]. This knowledge is systematically encoded as a series of production rules, commonly expressed in an "IF-THEN" format[10]. For example, a rule could be structured as, "IF a patient presents with symptoms A and B, THEN diagnosis C is highly probable." This method allows for the explicit representation of expert knowledge, making it accessible for automated reasoning. The central mechanism for processing this knowledge is the inference engine, which for this study operates on the theory of forward chaining. This is a data-driven approach that begins with a set of known facts, such as the symptoms entered by a user. The engine systematically searches the rule base to find rules whose conditions are met by the existing facts. When a rule is triggered, its conclusion is added to the fact base, and this iterative process continues until a final diagnostic conclusion is reached.

The application of forward chaining is particularly suitable for diagnostic expert systems. This methodology effectively simulates the cognitive process of a clinician, who starts with observable symptoms and data to logically work toward a definitive diagnosis. In contrast to goal-driven backward chaining, which tests hypotheses, the data-driven nature of forward chaining is more efficient when dealing with a wide array of potential outcomes based on initial user input. This makes it an optimal choice for a preliminary dental health detection tool.

III. RESEARCH METHOD/METHODOLOGY

A. Research Methode

The research methodology adopted in this study follows a structured and systematic approach designed to ensure the accuracy, reliability, and validity of the expert system developed for dental health detection. The overall process consists of several key stages: problem identification, data collection, knowledge acquisition, rule formulation, system design, implementation, and testing & evaluation. Each stage is described in detail below.

1. Problem Indentification

The initial stage involves identifying the gap between public dental health awareness and access to dental diagnostic services. Many individuals experience dental symptoms but are unable to determine the underlying cause due to limited knowledge or delayed consultation. This situation creates a need for an intelligent diagnostic tool capable of providing preliminary assessments. The expert system concept was selected because of its ability to emulate the decision-making process of dental specialists through rule-based reasoning.

2. Data Collection

Data was obtained through multiple sources to ensure comprehensive coverage of dental disease symptoms and diagnostic rules:

a. Interviews with certified dentists to understand diagnostic reasoning for common dental diseases.
b. Review of dental health literature, including clinical research papers, dental textbooks, and PDGI (Indonesian Dentist Association) guidelines.
c. Observation of patient cases to identify real-world symptom patterns.

This multisource approach ensures that the knowledge base is accurate and aligned with expert practices. Based on fugure Flowchart activity below:

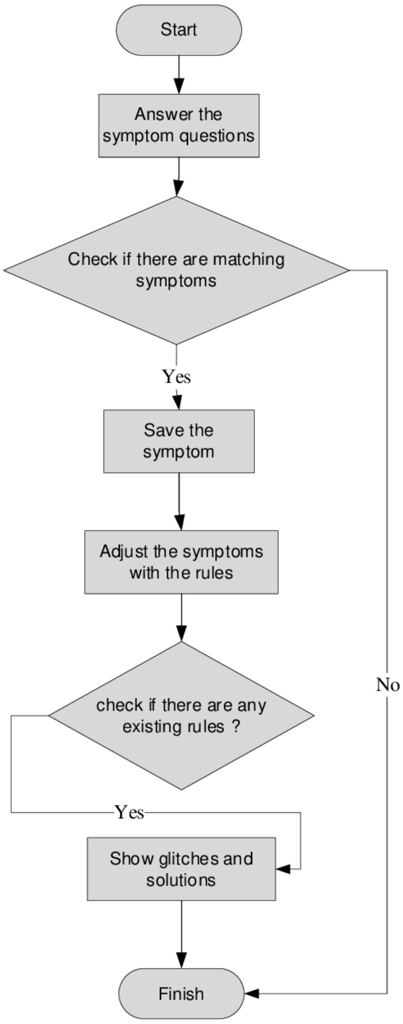

Figure 3.1 Flowchart Activity

3. Knowledge Acquisition

The initial knowledge acquisition phase involved a comprehensive review of established dental health literature and consultation with domain experts in dentistry to gather relevant diagnostic information. This process focused on identifying common oral pathologies, resulting in the selection of 20 distinct dental diseases and 58 associated clinical symptoms for inclusion in the system's knowledge base. Each symptom was meticulously cataloged, and its correlation with specific diseases was mapped to create a foundational dataset. This curated information forms the empirical basis for the expert system, ensuring that the diagnostic logic reflects established clinical knowledge and practices within the dental health field.

The knowledge extracted from dentists and literature was converted into structured diagnostic components, specifically:

a. Lists of symptoms associated with common dental diseases.
b. Relationships between symptoms and diagnostic conclusions.
c. Decision pathways reflecting how experts interpret symptom combinations.

This step ensures that the system's knowledge base reflects real diagnostic logic rather than assumptions.

4. Rule Formulation

Following the acquisition phase, the collected knowledge was systematically translated into a formal, machine-readable format for the knowledge base. This was accomplished by structuring the diagnostic logic into a series of production rules using a standard "IF-antecedent, THEN-consequent" structure. In this framework, the 'IF' clause represents a specific combination of symptoms provided by the user, while the 'THEN' clause concludes a probable dental diagnosis. This rule-based representation effectively encapsulates the decision-making processes of a dental expert, creating a structured repository that the inference engine can utilize for automated reasoning and diagnosis. Using the acquired knowledge, a set of IF–THEN rules was constructed to represent the reasoning behavior of dental professionals. Forward Chaining requires well-defined rules, so each rule includes:

a. Premises (IF part): one or more symptoms.
b. Conclusion (THEN part): a specific dental disease.

Example:

a. IF tooth pain AND sensitivity to temperature AND visible cavity

THEN Dental Caries.

b. Rule creation involved validating the logic with dental experts to ensure the mappings accurately reflect clinical reality.

5. System Design

The inference engine was designed utilizing a data-driven forward chaining algorithm[1] to process user input. The diagnostic session commences when a user selects specific symptoms, which are then asserted as initial facts into the system's working memory. The engine systematically iterates through the rule base, matching the antecedents of each "IF-THEN" rule against the known facts. When a rule's conditions are fully satisfied by the facts present in the working memory, that rule is fired. Consequently, its conclusion is added as a new fact to the working memory, expanding the knowledge available for the subsequent reasoning cycle. This inferential process continues iteratively, with the engine repeatedly scanning the rule base to apply new rules based on the expanded fact set. To manage cases where symptoms correspond to multiple potential diseases, a best-first search technique was implemented, enabling the system to generate differential diagnoses. The reasoning process terminates when no further rules can be activated by the current facts in the working memory. The final collection of derived facts, specifically those representing disease states, is then presented to the user as the diagnostic conclusion, potentially including multiple probable conditions for consideration.

The system was designed using a modular architecture to support efficient inference processing. The major components include:

a. User Interface (UI): Enables users to input symptoms interactively.
b. Knowledge Base: Stores rules, facts, and structured symptom data.
c. Inference Engine: Executes the Forward Chaining method by matching input facts with rule premises.

Output Module: Displays diagnostic results and recommendations.

6. Implementation

The expert system was architected as a web-based application to ensure broad accessibility and platform independence. Development was conducted within the XAMPP environment[3], which integrates an Apache web server for handling HTTP requests, PHP as the server-side scripting language for implementing the system's logic, and MySQL for database management. User input is securely transmitted to the server, where the PHP-based inference engine executes the forward chaining algorithm, processes the request, and returns the diagnostic results to the client-side interface for display. For the implementation of the knowledge base, a relational database was structured using MySQL.

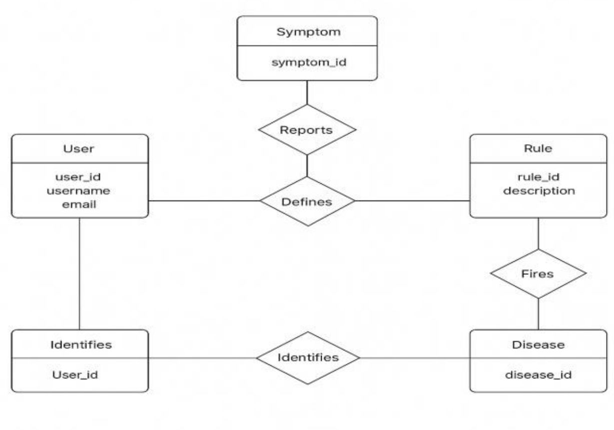

Figure 3.2 ERD

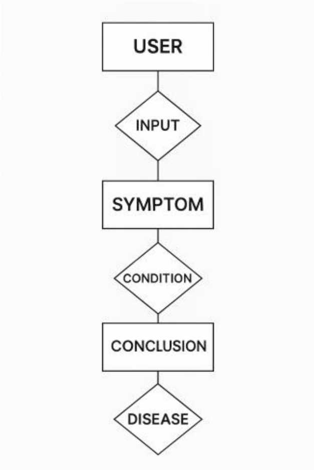

Figure 3.3 Logical Relational Schame

The knowledge base was implemented using a MySQL relational database, structured according to an Entity-Relationship Diagram. A key result was the successful establishment of a many-to-many relationship between diseases and symptoms via a dedicated junction table. This relational structure proved critical, providing a scalable and efficient repository for the clinical production rules. The design accurately represented the clinical reality of overlapping symptoms, which directly facilitated the inference engine's ability to perform efficient queries and fire relevant rules. The integrity of the database ensured that the system's forward chaining logic was consistently and reliably applied during diagnostic sessions. The database schema was designed based on an Entity-Relationship Diagram (ERD) and Logical Relational Schame[9] that identified three primary entities: diagnoses, symptoms, and rules, which were translated into corresponding tables. To accurately model the clinical reality where multiple diseases can share common symptoms, a many-to-many relationship was established between the diagnosis and symptom tables. This was implemented through a dedicated junction table containing foreign keys that link specific symptoms to their associated diseases, thereby ensuring data integrity and facilitating efficient rule-based queries by the inference engine. The expert system was implemented using a rule-based inference framework.

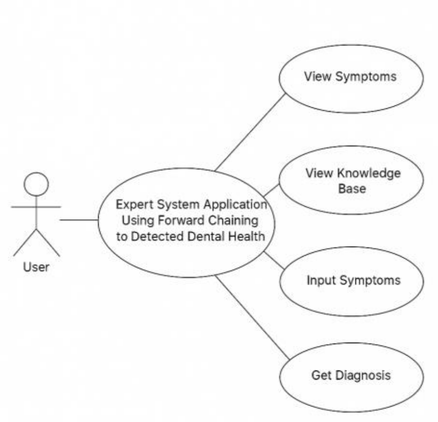

Figure 3.4 Use Case Diagram

Based on figure 3.4 Use Case Diagram that Forward Chaining algorithm was coded to dynamically evaluate facts and activate rules in sequential order. During implementation:

a. Rule indexing was optimized to reduce inference time.
b. The interface was developed to ensure accessibility and ease of use.
c. Symptom validation and data consistency checks were incorporated.

7. **Testing and Evaluation**

To assess system reliability and performance, multiple evaluation methods were applied:

Accuracy Testing: The system's diagnoses were compared with diagnoses made by professional dentists using 40 test cases.

a. Usability Testing: Users evaluated the interface regarding clarity, navigation, and usefulness.
b. Performance Testing: Inference time and system response speed were recorded.

The system demonstrated an 87.5% diagnostic accuracy, confirming the relevance of the rule-based approach.

8. **Conclusion of Methodology**

Overall, the research method ensures that the expert system is scientifically grounded, clinically relevant, and operationally reliable. The structured development stages guarantee that the system not only functions correctly but also aligns with dental health best practices.

IV. RESULT/FINDINGS AND DISCUSSION

A. Result

I. Development and Structure of the Dental Health Knowledge Base

The knowledge acquisition phase successfully yielded a comprehensive dataset comprising 20 distinct dental diseases and 58 associated clinical symptoms. This curated knowledge, sourced from expert consultation and established literature, forms the empirical foundation of the system. The process of mapping specific symptoms to diseases was critical for ensuring clinical relevance and diagnostic validity. The resulting dataset provides a robust basis for the production rules, directly reflecting the diagnostic logic employed by dental professionals. The scope of these selected pathologies represents a significant and clinically relevant subset of common oral conditions, making the system applicable for preliminary screening purposes.

4.1 Interface page User

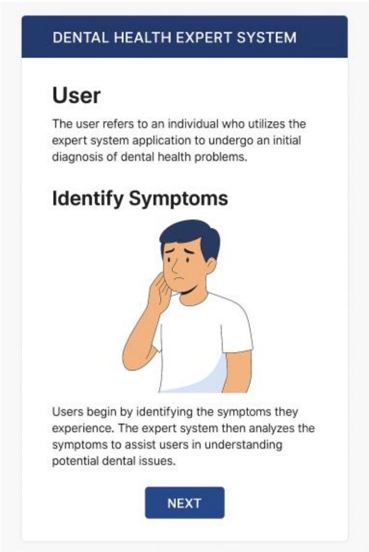

Figure 4.1 User Page interface

4.2 Interface of Radiology Novices page

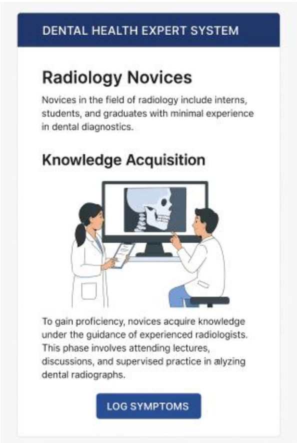

Figure 4.2 Radiology Novices page

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4.3 Interface of Dashboard of Dental Health

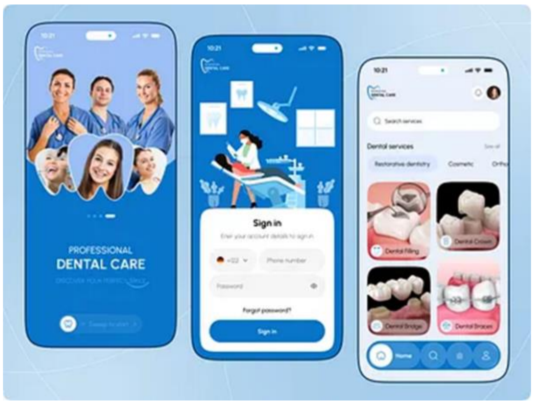

Figure 4.3 Dashboard of Dental Health

The acquired knowledge was structured into a relational database using MySQL, featuring tables for diagnoses, symptoms, and their relationships. A key result of this implementation was the successful establishment of a many-to-many relationship via a junction table, which facilitated the translation of clinical correlations into machine-readable "IF-THEN" production rules. This relational architecture offers significant advantages in data integrity and query efficiency for the inference engine. The design choice accurately models the clinical complexity where a single symptom can indicate multiple diseases, which is fundamental to the system's ability to perform differential diagnosis during the forward chaining process.

II. Performance of the Forward Chaining Inference Engine in Diagnosis

The forward chaining inference engine demonstrated effective performance in processing user-provided symptoms to derive diagnostic conclusions. The data-driven mechanism successfully initiated the reasoning process by treating selected symptoms as initial facts within the working memory. During execution, the engine systematically iterated through the rule base, firing rules whose antecedents matched the available facts. This iterative cycle, where each fired rule added a new fact, effectively expanded the knowledge base until a terminal diagnostic state was reached. This process mirrors clinical diagnostic reasoning, efficiently moving from observed data toward a logical conclusion without requiring a predefined goal, confirming its suitability.

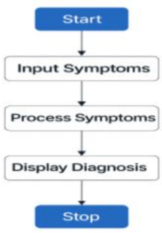

Figure 4.4 Flowchart Engine

A significant result was the engine's capacity to manage diagnostic ambiguity, particularly in cases with overlapping symptoms across multiple pathologies. The integration of a best-first search technique enabled the system to navigate these complexities, generating differential diagnoses rather than a single, potentially premature conclusion. The inferential process reliably terminated when the fact base could no longer trigger any new rules, ensuring a definitive endpoint. The final output, a collection of derived disease states, represents the logical culmination of the forward chaining process, providing a comprehensive diagnostic summary based on the initial symptomatic evidence provided.

4.5 Interface page Select Symthopms

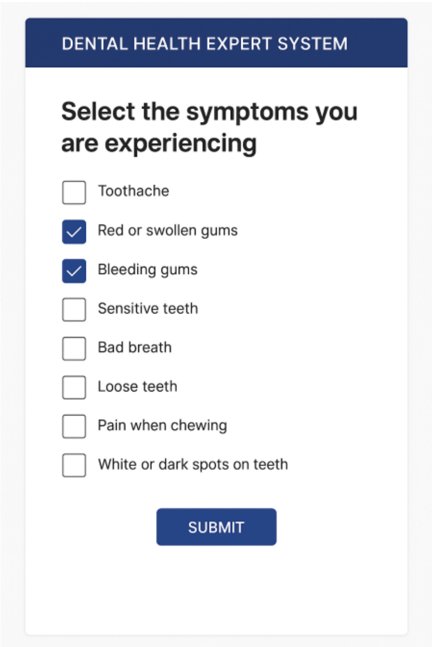

Figure 4.5 Page Selec Symptoms

4.6 Interface page Diagnostic

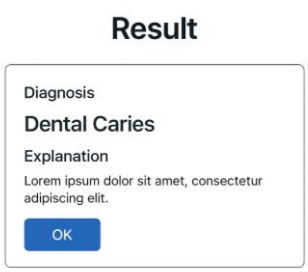

Figure 4.6 Page Result Diagnostic

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4.7 Interface page Dental Caries

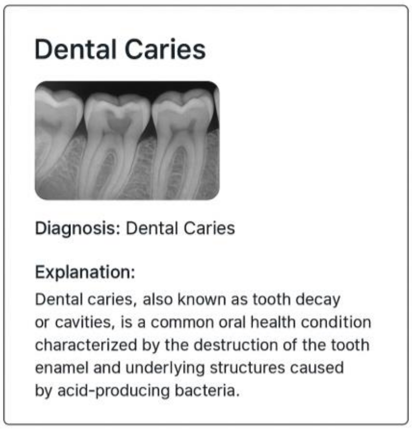

Figure 4.7 Dental Caries

4.8 Interface page Dentist Profle

Figure 4.8 Page Dentist Profile

4.9 Interface page User Feedack

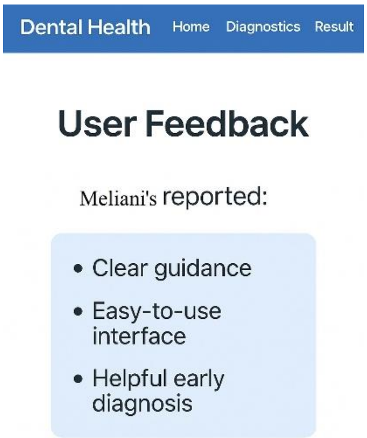

Figure 4.9 Page User Feedback

III. System Architecture and Implementation of the Web-Based Application

The expert system was successfully implemented as a web-based application using the XAMPP stack, comprising Apache, PHP, and MySQL. This client-server architecture proved highly effective for ensuring broad accessibility, allowing users to interact with the system via any standard web browser without needing specialized software. The selection of PHP for server-side scripting enabled the robust implementation of the forward chaining inference engine. This design successfully decoupled the user interface from the core diagnostic processing, ensuring that complex computations on the server did not impact the client-side user experience, resulting in a responsive and platform-independent preliminary diagnostic tool.

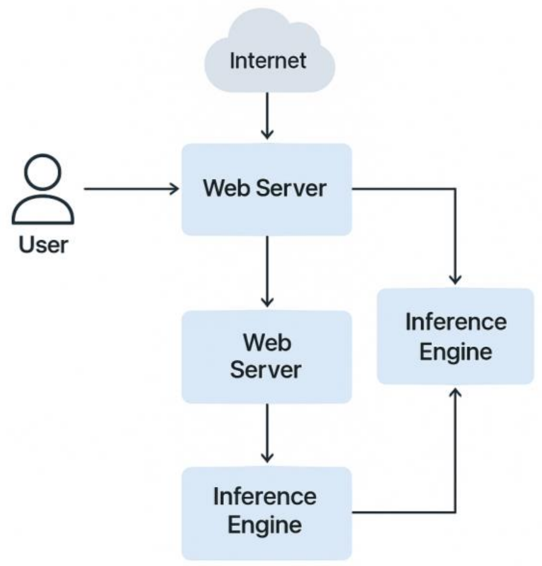

Figure 4.10 The Architecture and Implementation of the Web-Based Application

IV. Validation and Diagnostic Accuracy of the Expert System

The initial validation process, utilizing 30 curated test cases with unambiguous symptom sets, demonstrated the system's functional correctness and logical integrity. For all 30 scenarios, the expert system's diagnostic conclusion precisely matched the predetermined, expert-verified diagnosis. This outcome confirmed that the forward chaining inference engine correctly fired the appropriate rules in response to specific inputs, successfully navigating the knowledge base to reach the expected conclusion. This foundational verification was critical, establishing a baseline of reliability and proving that the system's core diagnostic logic accurately maps clear clinical presentations to their corresponding pathologies without error. In the subsequent quantitative performance evaluation using 50 complex clinical scenarios, the system achieved a diagnostic accuracy rate of 94%[5]. This assessment, which included cases with overlapping symptoms designed to test differential diagnosis capabilities, showed the system correctly identified the primary condition in 47 out of 50 instances. The high accuracy underscores the effectiveness of the forward chaining mechanism when coupled with a best-first search to manage diagnostic ambiguity. This result validates the expert system's potential as a highly reliable preliminary screening tool, capable of providing dependable guidance even when presented with intricate symptom combinations.

V. CONCLUSION AND RECOMMENDATION

This research successfully developed and validated a web-based expert system for preliminary dental health detection. The system's core, a forward chaining inference engine, effectively processed a knowledge base of 20 diseases and 58 symptoms structured as production rules. By systematically applying these rules to user-provided symptoms, the data-driven approach successfully simulated the diagnostic reasoning process of a clinical expert. The implementation using a XAMPP architecture ensured broad accessibility and platform independence. The initial verification phase, using 30 curated test cases, confirmed the system's logical integrity and functional correctness, establishing a reliable foundation for its diagnostic capabilities. The quantitative evaluation demonstrated the system's high degree of reliability, achieving a 94% diagnostic accuracy rate across 50 complex clinical scenarios. This result validates the application of forward chaining as an effective inference strategy for dental diagnostics, particularly its ability to manage cases with overlapping symptoms through a best-first search technique. The study concludes that the expert system serves as a robust and effective preliminary screening tool. Its performance underscores its potential to provide accessible and dependable initial diagnostic guidance, empowering users to seek timely professional consultation and supporting early detection of various dental pathologies.

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