Knowledge-based Decision Support System for Personalised Training

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Abstract:

Modern lifestyles and increased awareness of healthy living highlight the need for personalised fitness and nutrition plans. However, designing such plans remains complex, requiring the integration of diverse biometric data and individualised goals. This paper presents a Knowledge-Based Decision Support System (KDSS) that automates the generation of weekly personalised exercise and dietary recommendations. By analysing parameters such as height, weight, body water percentage, and protein intake, the system employs predefined rules and inference mechanisms to tailor guidance aligned with user objectives, including weight loss, maintenance, or muscle gain. The KDSS bridges the gap between general health guidelines and individualised interventions, offering intelligent, goal-specific support. Its architecture and reasoning framework are designed to deliver accurate and actionable plans, facilitating user motivation and adherence. Validation experiments confirm the system's effectiveness in supporting health and fitness outcomes. The proposed solution not only streamlines the planning process but also offers scalability for integration with wearable devices and real-time data analytics. This approach provides practical value for both end users and fitness professionals, contributing to improved quality of life through informed, personalised decision-making. The objective of this paper is to evaluate and develop a Knowledge-Based Decision System that will automatically generate personalised weekly exercise plans based on individual parameters.

Keywords:

Knowledge-Based Systems, Decision Support System (DSS), Personalized Training, Personalized Nutrition, Biometric Data Analysis, Fitness Recommendation, Automated Planning

1. Introduction

The rapid pace of modern life, coupled with an increasing awareness of healthy living, has heightened the demand for personalised approaches in physical activity and nutrition. Over recent decades, personalised nutrition and training have emerged as standard practices to support individuals in achieving their fitness goals effectively and safely.

Despite their recognised importance, the development of truly personalised exercise and nutrition plans remains a complex challenge. Creating effective exercise programs requires careful consideration of multiple individual-specific factors to optimise outcomes and minimise risks such as injury. Similarly, adjusting meal portions and food consistency to meet nutritional guidelines is often difficult for users, who may rely on a limited range of "safe" options, thereby risking nutritional imbalance or deficiency [1]. Furthermore, modifications to food texture and consistency lack standardisation, as they depend on local clinical practices, cultural habits, and users' education and adherence to recommendations [2].

In response to the challenges, knowledge-based decision support systems (KDSSs) offer a promising solution by providing intelligent, automated assistance tailored to individual parameters. These systems integrate expert knowledge with biometric data analysis to support decision-making, bridging the gap between general fitness guidelines and personalised training and nutrition plans.

The motivation for this paper stems from the need to develop a system capable of analysing biometric parameters such as height, weight, body water percentage, and protein intake to generate personalised exercise and nutrition recommendations. The primary objective is to deliver accurate, automated support that aligns with individual goals, including weight loss, weight maintenance, or muscle gain. Leveraging predefined rules and inference mechanisms, the proposed ontology-based Decision Support System (DSS) produces weekly, tailored recommendations, facilitating effective planning and enabling users to make evidence-based decisions that improve their health and quality of life. Moreover, trainers and fitness professionals often face the daunting task of processing extensive biometric data, scientific research, and nutritional guidelines to provide up-to-date, personalised advice. Given the complexity and time constraints involved in manually integrating this information [3], KDSSs are essential tools that enhance the delivery of precise and individualised guidance [4].

The paper is structured as follows: Following the introduction, a comprehensive and systematic review of knowledge-based systems is presented, with particular emphasis on their development and application in decision support for fitness and nutrition. The subsequent section focuses on the design and implementation of the proposed decision support system. It provides detailed descriptions of the methods used for collecting and analysing input parameters (such as height, weight, body water percentage, and protein intake), as well as the rules and algorithms that generate exercise and nutrition recommendations tailored to specific goals, including weight loss, maintenance, and muscle gain. This section also addresses system architecture, inference mechanisms, and knowledge management, alongside testing and validation processes that evaluate the system's accuracy, precision, and practical applicability. Finally, the paper concludes with a summary of the key findings and contributions, reflections on the results, and recommendations for future research and development. Additionally, it discusses the limitations and challenges encountered, as well as potential avenues for enhancing the system through further adaptation and integration with emerging technologies.

2. Related Work: Personalised Exercise, Individual Goals, and Adaptive Training Systems

Regular physical activity is fundamental for both physical and mental health. It helps prevent and manage chronic diseases such as type 2 diabetes, heart disease, and obesity, while also supporting mental well-being and functional longevity. However, exercise is not universally effective in the same way for everyone. As Dr. William Kraus explains, "The benefits vary by type, intensity, and amount of exercise" [5]**.** Different modalities of physical activity yield different physiological outcomes. Moderate-intensity, longer-duration exercises such as brisk walking are particularly effective at lowering blood glucose, thus playing a preventive role in the development of type 2 diabetes [5]**.** In contrast, high-intensity workouts, which significantly elevate heart rate, have shown greater effectiveness in reducing LDL cholesterol, thereby improving cardiovascular risk profiles. Hence, defining individual goals—such as fat loss, strength gain, endurance improvement, or mental clarity—is critical to selecting the most suitable form of activity.

A significant challenge is the wide variability in individual responses to identical training programs. While some participants experience substantial improvements, others may see minimal or no change. This has led to classifications such as 'responders' and 'non-responders', although many researchers now argue that these are oversimplified [6]. They emphasise that responses are not binary but exist on a graded spectrum—a concept supported by the emerging field of kinesio-dynamics. Booth and Laye [7] suggest using terms like "high" and "low sensitivity" to reflect the nuanced biological responses better. Notably, individuals who do not exhibit muscle hypertrophy may still experience improvements in strength or cardiovascular metrics [8].

Genetic predispositions, existing medical conditions, lifestyle factors, and environmental influences all modulate an individual's responsiveness to exercise. According to Joyner and Green, exercise provides significantly broader health benefits than those reflected by traditional risk factor measurements alone, highlighting its direct protective effects on the cardiovascular system **[9]**. Despite numerous studies supporting this notion, a unified framework that integrates this complexity into widely applicable guidelines remains elusive [10].

Dr. William Kraus highlights the importance of personalised approaches in maximising exercise-related outcomes. The personalised exercise aims to tailor programs based on a person's unique physiological traits, lifestyle, and health status. According to Dr. Marcas Bamman, the objective is to design an exercise plan that delivers optimal benefit to everyone **[5].** This involves setting specific short- and long-term goals, ensuring safety, and promoting long-term adherence through enjoyable and effective training choices.

With growing access to wearable health technology and personal data tracking, personalised, adaptive training plans are becoming more accessible and data-informed. This evolution allows individuals not only to achieve targeted health outcomes but also to reduce injury risk and avoid exercise fatigue, ensuring long-term success and adherence.

Papers such as [11], [12], and [13] explain advanced algorithms and learning models that can be used to recognise patterns in user data and personalise training sessions. The combination of these papers allows the development of advanced systems that can learn from experience and propose the most appropriate approaches to personalised training. Reference [14] emphasises the importance of developing AI systems that provide transparency and clarity in the decision-making process. For personalised training systems, this is especially important because users and instructors need to understand why a certain decision or recommendation was made. Thus, the application of AI increases trust in the system and allows for better interaction and adaptation according to user feedback.

In these papers, the focus is on the application of artificial intelligence and methods for adapting training content depending on the individual needs and context of the user. The papers [15], [16], and [17] emphasise the importance of personalised learning through innovative virtual trainers and training frameworks, which use real-time data and analytics to create fully customised training. In the paper, [16] uses industrial applications for personalised training in new working conditions (Industry 5.0), which is of particular importance for the implementation of knowledge-based systems in the professional environment. This helps to define the methodology and technological solutions that support dynamic and adaptive decision-making in training systems. According to [18] and [19], the key concepts of knowledge-based systems and their role in intelligent tutoring systems are used. These works are important for creating a system that not only collects data, but also transforms it into useful knowledge, which allows for personalised and effective training based on recognising the specific needs and challenges of the user. Within the framework of personalised training, these concepts from papers [20] and [21] enable the integration of different information sources, such as real-world sensor data or the Internet of Things (IoT), making the system more intelligent and capable of adapting training to the specific environment and conditions. This supports the implementation of systems that use big data and contextual analysis to improve the accuracy and efficiency of personalised training.

The references included are used to support improvements in the system architecture, enhance the methodology, and propose more effective solutions to the challenges addressed in this paper. Certain concepts related to knowledge representation, integration of heterogeneous data, and system adaptability are drawn from [22], [23], and [24], helping shape a more dynamic and personalised approach. Moreover, the idea of using real-time data streams for informed decision-making, particularly in the context of personalised training, is inspired by the integration models found in [25] and [26]. These works emphasise the importance of individual data profiles and digital literacy, which align directly with the goals of this system. Finally, privacy and security concerns, as outlined in [27], are used to inform the protective measures within the decision-making process, ensuring trust and compliance.

In conclusion, all these references form a comprehensive foundation for designing a knowledge-based decision-making system for personalised training, combining machine learning, adaptive instruction, artificial intelligence, and contextual data integration. By leveraging both theoretical models and real-world applications, the system is equipped to deliver customised training experiences that respond to individual needs, environments, and performance feedback - ensuring continuous improvement and informed decision-making.

3. Knowledge-based Decision Support System for Personalised Training

To address the growing need for personalised support in planning physical activity, we propose a knowledge-based decision support system designed to generate individualised training programs. The system is built on principles of artificial intelligence and knowledge representation, enabling automated exercise selection based on parameters such as height, weight, body water percentage, protein intake, and defined goals (e.g., weight loss, maintenance, or muscle gain). It is implemented as a web application with a scalable architecture, integration of machine learning components, and potential for future expansion through additional technologies.

To evaluate the effectiveness of this system in practical conditions, a combination of real and experimental data was used for testing.

For the evaluation of the proposed Knowledge-Based Decision Support System (KDSS), data were obtained from the Mendeley Data Repository (Dataset: Fitness and Nutrition Data for Personalized Training, DOI: https://data.mendeley.com/datasets/zw8mtbm5b9/1). From this source, 1,000 representative records were selected to provide a relevant and diverse sample in terms of fitness levels, body composition, and nutritional profiles. In addition, several personal test records were used to examine the full operation of the web application, including data entry, rule-based processing, and the generation of personalised exercise and nutrition recommendations. Combining these external and experimental datasets offered a practical and balanced foundation for assessing the system's performance, accuracy, and suitability for real-world use.

3.1. Technologies for KBS development

Technologies suitable for the development of small- to medium-scale applications were used in the implementation of the system, with only selected components from larger, more complex libraries being utilised. The system architecture follows the Model-View-Controller (MVC) design pattern and adheres to a RESTful architectural style, as illustrated in Figure 1.

On the client side, the application is built using Angular, a widely adopted frontend framework developed and maintained by Google. Angular facilitates the development of Single Page Applications (SPAs), allowing for dynamic content loading without requiring a full page reload. This capability significantly enhances the responsiveness and interactivity of the application—an essential feature for systems involving frequent user input, such as the exercise diary module.

Angular provides several key features that contribute to the efficiency and maintainability of the application: Component-based architecture – the user interface is structured as a collection of modular, reusable components, each encapsulating its own logic and view; two-way data binding – ensures automatic synchronization between the application's data model and its visual representation; built-in routing system – simplifies navigation and state management across different views within the application.

These features collectively support a scalable, maintainable, and user-friendly client-side experience, aligning with the overall goals of the system.

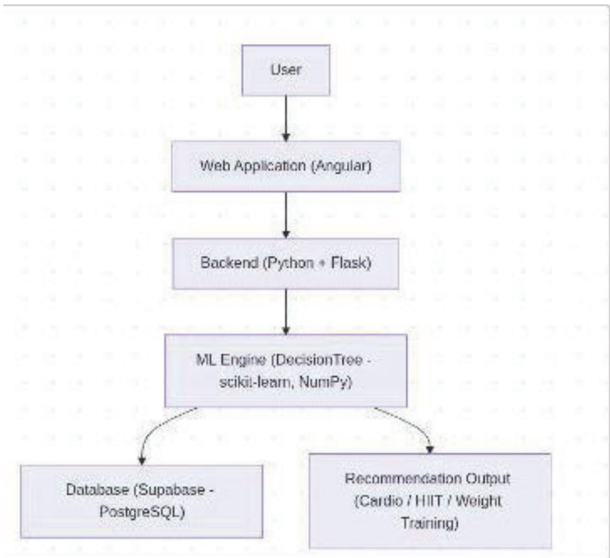

Figure 1: Architecture and technology stack diagram

The server-side component of the application is developed in Python, utilising Flask—a lightweight yet powerful microframework for web development. Flask was selected due to its flexibility, minimalistic design, and strong community support. Its modular architecture makes it particularly well-suited for projects requiring rapid development while ensuring maintainability and code clarity over time.

In this system, Flask serves several key roles: processing HTTP requests originating from the client-side application; communicating with the database through the Supabase API; integrating with the machine learning (ML) model, enabling real-time generation of training recommendations; and constructing a RESTful API with well-defined endpoints, documented using Swagger for clarity and ease of use.

For data storage and management**,** the system leverages Supabase, a cloud-based backend-as-a-service platform built on PostgreSQL. Supabase was chosen as it provides a robust and scalable solution that eliminates the need for manual server administration, thus simplifying backend development.

Unlike traditional databases, Supabase offers a comprehensive set of features that support modern web applications, including built-in user authentication and authorisation, support for real-time data synchronisation**,** an auto-generated REST API, built-in support for webhooks**,** serverless functions**,** and access control policies. Within the context of this application, Supabase is used for: storing user profile data and exercise logs**;** managing datasets used for training and validating the machine learning model; and verifying the accuracy of model-generated recommendations based on actual user feedback and performance.

An intelligent recommendation system has been integrated into the application, leveraging machine learning to predict personalised training plans based on user-provided input. This system is implemented using two core Python libraries: Scikit-learn, a widely used ML library, utilised here to implement the *Decision Tree Classifier* algorithm. This algorithm constructs a predictive model by learning from historical training data, producing decisions based on logical "if-then" rules and data partitioning; and NumPy, employed for efficient numerical computations, especially in the preprocessing of input data and postprocessing of model outputs.

This data-driven approach ensures that training recommendations are tailored to individual users, based on concrete examples and learned patterns rather than generalised or static rules. Key steps in the training process include model training, which is performed during application initialization using a predefined dataset. During training, accuracy checks are conducted by comparing the predicted outputs with the expected results to assess the performance of the model.

3.2. Graphic User Interface and functionalities

The application is designed to provide a simple and user-friendly experience, catering to both beginners and advanced users. Emphasis is placed on clear navigation, an intuitive layout, and easily accessible forms for data entry and review. This approach aims to promote regular use of the system and facilitate seamless monitoring of training progress.

One of the most critical components of any modern web system is secure user profile management, which is comprehensively addressed in this application. Several interrelated functionalities have been implemented to enable a complete cycle of user authentication and authorisation.

System access begins with user registration, during which individuals can create their personal profiles by completing a form that captures essential information—such as name, email address, and password. Input validation is performed to ensure accuracy and security. Upon successful data submission, the information is transmitted to the backend, where a new user record is created in the database using Supabase. To enhance security and prevent abuse, the system automatically sends a confirmation email containing an activation link. This link directs the user to a backend endpoint that activates their account, thereby verifying the email address and mitigating the risk of automated or fraudulent registrations.

Once the profile has been activated, users can log into the system via a dedicated login form using their email and password. During the login process, authentication is conducted through Supabase Auth, which returns a valid token upon successful verification. This token is used for secure session storage and subsequent communication with the backend. The system also supports detailed error reporting, contributing to a more robust and user-friendly experience.

The core component of the application is the exercise management and training log module. This module enables users to record, track, and analyse data related to daily physical activities, thereby forming the foundation for long-term progress monitoring and personalised fitness improvement.

The training log serves as a digital diary, offering not only a historical overview of completed training sessions but also a basis for further analysis and data-driven training recommendations. Users can input data for each training session through an intuitive web form that captures information such as the name of the exercise, number of sets, repetitions, and weight used (in kilograms).

Once submitted, the data is automatically displayed in a table summarising all completed exercises for the selected day. This visual representation provides: a quick overview of completed exercises; insight into training volume and intensity; motivation to maintain consistency in training routines.

The application includes a predefined set of exercises derived from commonly practised fitness movements. These are available via a dropdown menu in the input form, allowing users to select exercises without manually entering their details. Key benefits of this functionality include: time efficiency during data entry; standardised data formatting for easier analysis; enhanced usability for beginners who may be unsure which exercises to select.

In addition to predefined exercises, users have the option to create personalised exercises. When adding a new exercise, the user specifies a name and may optionally provide a description or set of instructions. Once created, the exercise is stored in the user's personal library for reuse in future sessions. This feature is particularly beneficial for: advanced users with customised training programs; rehabilitation exercises or non-standard physical activities.

One of the most valuable features of the system is the personalised training recommendation module, which adapts fitness programs to individual user needs, characteristics, and performance data. This is achieved through the implementation of a machine learning algorithm that intelligently analyses user input and generates highly relevant training suggestions.

Unlike traditional rule-based recommendation systems, this approach enables dynamic and automated decision-making that improves with the accumulation of data over time. Specifically, the application utilises the *DecisionTreeClassifierfrom* the Python scikit-learn library. This algorithm was selected for its interpretability, computational efficiency, and suitability for small to medium-sized datasets, which aligns with the current scale of the application.

The decision tree algorithm operates by hierarchically splitting data based on logical rules, thereby modelling decisions as intuitive "if–then" scenarios. This logic is easily understood by both developers and domain experts. The machine learning model is integrated into the backend, enabling real-time generation of recommendations immediately after the user inputs data.

Users can access a specialised web form to provide information such as age, gender, previous physical activity, fitness goals, number of weekly workouts, total body weight, and historical progress. This data forms an input vector for the machine learning model, which then outputs a personalised recommendation. The recommendation includes parameters such as training type, intensity, duration, and the number of sets or repetitions. The result is instantly displayed on the user interface (*Figure 2*).

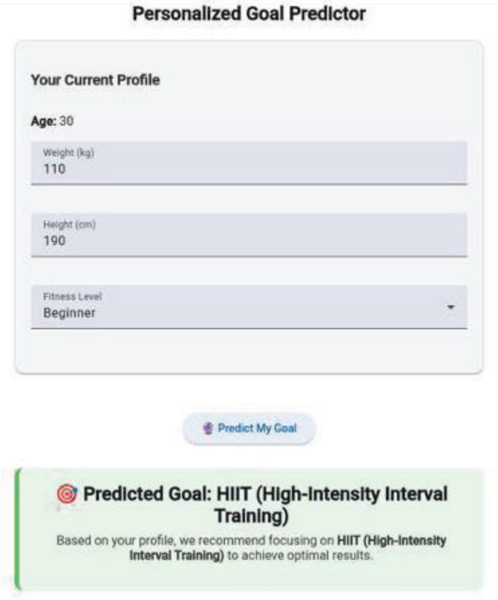

Figure 2 Personalized recommendation

The system maintains a history of the five most recent recommendations provided to the user. This functionality enhances transparency and user trust, while also offering valuable insights into the evolution of training guidance. This overview enables users to: compare the current recommendation with previous ones; analyse whether the system suggests increasingly complex or varied routines over time; and reuse earlier recommendations if they wish to return to a specific training approach.

In addition, the application automatically tracks significant changes in the user's body weight. This ensures that the recommendations remain contextually adaptive, rather than static, thereby supporting the user throughout their fitness journey. Upon detecting a substantial weight change, the system triggers a re-evaluation process, during which the machine learning model is re-invoked to generate an updated and personalised recommendation. This new suggestion accounts for: reduced energy levels; the need for modified or lower-intensity workouts; and the importance of preventing excessive physical exertion.

To further support the user experience, the system provides visual analytics of all data entered. Multiple types of graphs are used to enhance the visual representation of training history, making it easier for users to review their exercise progress and performance trends (*Figure 3).*

Figure 3: Graphic displaying user exercise logs

4. Conclusions

This paper demonstrates that the development and application of knowledge-based decision-making systems in the domain of personalised training hold significant implications for both industry and society. In the industrial context, these systems enhance the efficiency and quality of services within the sports and health sectors by enabling the automated and precise adaptation of training programs to individual needs. From a broader societal perspective, such systems promote the adoption of a healthy and active lifestyle by providing personalised support and motivation. They democratize access to high-quality services and expert recommendations, not only for professional athletes but also for the general population, including individuals with specific health requirements and those undergoing rehabilitation.

Moreover, the implementation of intelligent technologies and decision-making systems supports the ongoing digital transformation in health and sports. This advancement fosters innovation, creates new employment opportunities, and contributes to overall economic growth. These systems encourage the integration of multidisciplinary knowledge and collaboration across fields such as informatics, sports science, medicine, and engineering. Overall, the significance of knowledge-based decision-making systems lies in their ability to serve as a bridge between technological innovation and practical application, delivering measurable benefits to both industry and public well-being.

Through a review of the theoretical foundations, system architecture, knowledge representation, and inference mechanisms, it has been established that such systems are powerful tools for supporting complex and dynamic processes, such as the personalisation of training programs in alignment with users' individual goals and evolving needs. Special attention was given to emerging trends, including the integration of artificial intelligence (AI), machine learning (ML), Big Data, and the Internet of Things (IoT). These technologies significantly expand the potential for developing intelligent, self-improving systems capable of adapting to real-time user data and environmental factors. Prospects point toward the development of intelligent assistants and robotic systems in personalised training, marking a shift toward hybrid human–machine collaboration aimed at optimising training outcomes.

A critical aspect of these systems is the ongoing maintenance and updating of the knowledge base, which is equally important as its initial construction. This continuous process is essential for ensuring reliability, efficiency, and relevance in real-world, dynamic environments.

In the domain of personalised training, where user needs and scientific understanding are in constant evolution, this adaptability is a key prerequisite for long-term success. The challenges associated with constructing and maintaining a robust knowledge base should be viewed not as obstacles but as opportunities for the creation of more mature, flexible, and effective systems.

By systematically addressing these considerations, it becomes possible to ensure the long-term applicability, accuracy, and trustworthiness of personalised training systems.

In summary, the scientific contribution of this work lies in the development of a Knowledge-Based Decision System that automates the generation of personalised exercise plans through rule-based reasoning. The proposed system integrates diverse biometric parameters with individual user goals, providing a scalable and adaptable framework for customised fitness support. Experimental validation confirmed the system's effectiveness in producing recommendations aligned with user objectives, thereby demonstrating its practical utility and methodological robustness.

Future research should focus on enhancing self-learning capabilities through the integration of artificial intelligence (AI) and the Internet of Things (IoT), further advancing the system's adaptability, real-time responsiveness, and overall contribution to improving health outcomes.

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