ORIGINAL ARTICLE

Developing a Mobile-based Educational Game to Enhance Dietary Habits for Type 2 Diabetes Patients through Artificial Intelligence Algorithms

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ABSTRACT

This study aimed to design a mobile digital game to assist individuals with type 2 diabetes in better understanding food calories and the glycemic index, ultimately enhancing their management of the condition. The game was developed using fuzzy logic and initially tested in MATLAB 2018 before being converted to C# in Visual Studio and implemented in Unity. To develop the game, food calorie and glycemic index values were integrated into a fuzzy input system, utilizing a triangular membership function. The fuzzy output was translated into a numerical value through the centroid defuzzifier, employing the Mamdani fuzzy inference engine for determination. The outcome of this study was the development of a mobile game named "Diabetic Amoo," specifically designed for diabetic patients. Players advance through the first episode by correctly selecting appropriate food items, while the second stage focuses on educating them about low-sugar and low-calorie foods. Players receive ratings for their choices that range from "very bad" to "very good," with the goal of achieving a "very good" rating. By emphasizing patient education, such games can enhance motivation for self-care and improve adherence to diabetes diets and other health conditions.

Keywords: Mobile Health, Gamification, Video Games, Fuzzy Logic, Type 2 Diabetes Mellitus

INTRODUCTION

In recent years, the increasing popularity of video games has significantly influenced the field of digital health (1). Serious games are a category of games developed for specific purposes. They are applied in various health-related areas, including medical education, interventions for adolescents suffering from anxiety disorders, mental health assessments and treatments, and support for patients with diabetes (2-6).

Games play a significant role as a digital intervention for managing diabetes, accessible through the Internet and a wide range of mobile devices (5–6). For example, in a study involving three digital games designed to educate participants about nutrition and calorie control, six diabetic patients were included in the pilot. The results indicated that mobile-based games could be a promising new method for delivering effective educational content. (7). Thus, games serve as an active learning method for teaching fundamental diabetes concepts (8). However, there has been limited development and evaluation of nutrition games, although they have shown promise in encouraging dietary and physical activity behaviors. (9).

In addition, the use of artificial intelligence (AI) for video game designing is increasing dramatically (10). Games and AI have a long history together. Historically, using AI in developing games has been around for a long time. Before AI was recognized as a field, early computer science pioneers wrote programs to test whether computers could solve tasks requiring “intelligence.” Alan Turing, a famous computer scientist, invented the Minimax algorithm and used it to play chess. Tic Tac Toe was one of the first software games, programmed in 1952 by Douglas as part of his doctoral thesis at Cambridge. A few years later, Arthur Samuel was the first to invent a form of machine learning that now uses a program that

has learned to play chess against itself (11). AI in gaming is used in various parts of a video game, including animation control, player guidance, character assembly, routing, planning, procedural generation, tactical and strategic thinking, and learning (12).

AI methods are highly useful for data analysis and significantly aid in prediction and diagnosis, which can be categorized into different groups (13-14). Fuzzy logic is a method of AI that uses multi-valued logic, allowing the logical value of variables to be any real number between 0 and 1. Fuzzy systems employ fuzzy sets to handle incorrect and incomplete data. As a result, fuzzy models can effectively represent ambiguous expressions found in natural language (15). In today's world, as discussions about AI systems grow, fuzzy logic emerges as a leading approach that fosters human-like capabilities. Consequently, fuzzy logic is vital for enhancing these human-like traits in AI (16).

Many diabetic patients have reported that one of the most challenging aspects of self-care is adhering to a healthy diet and making necessary dietary changes (17). Therefore, the current study aimed to design a digital game that utilizes fuzzy techniques to assist type 2 diabetic patients in enhancing their awareness of diet and a healthy lifestyle in managing their health.

METHODS

The game being examined was developed by the researchers and was called Diabetic Amoo. Diabetic Amoo was an endless runner game that has been one of the most popular mobile game genres in recent years. As the name implies, these games are endless, meaning the player should continue playing until they encounter an obstacle and lose, at which point they must restart to achieve their aim (18). This study received ethical approvals from the Ethics Research Committee of Ahvaz Jundishapur University of Medical Sciences with code IR.AJUMS.REC.1397.909.

Game Plan

In Diabetic Amoo, players learned about foods that contain varying levels of sugar (glycemic index) and calories. To successfully complete each episode of the game, it was essential for players to avoid foods high in glycemic index (GI) and calories and to choose options that meet their dietary goals.

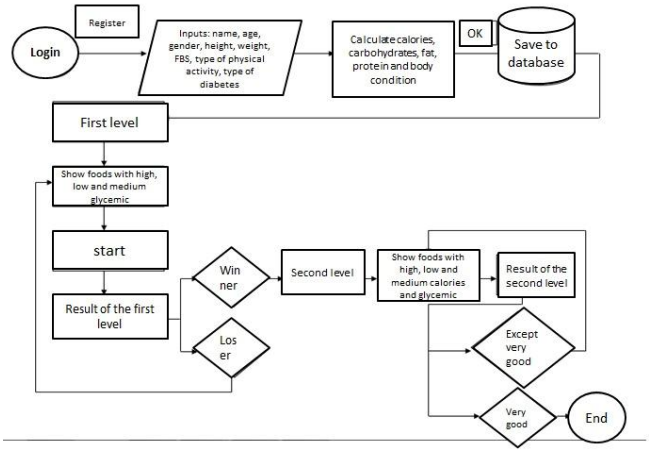

FIGURE I. THE DIAGRAM OF THE GAME PLAN

Diabetic Amoo consisted of two episodes. The first episode involved education on low-sugar foods and ended when the player made the correct choice, allowing them to progress to the second episode. The second episode focused on education regarding both low-sugar and low-calorie foods. Players resulting in this stage could be categorized as ‘very bad’, ‘bad’, ‘average’, ‘good’, and ‘very good’. The game continued until the player achieved a "very good" result, thereby winning. Figure 1 illustrates the game plan.

Variables

The input variables in the fuzzy system were the glycemic index and calories of the food. These values were determined according to the food used in the game (Table 1). The output variable was the system's analysis of the player's choices, including very good, good, average, bad, and very bad (Table 2).

TABLE I. THE DATASET FEATURES

Linguistic value	Calorie (%)	GI
Low	<50	<55
Moderate	50-100	70-55
High	>100	>70

TABLE II. THE PLAYERS’ SCORE AS OUTPUT VARIABLE

Linguistic value	Value (%)
Very bad	<25
Bad	25-50
Average	50-75
Good	75-100
Very good	100

Membership function

The trial-and-error process demonstrated a lower error rate and a more accurate membership degree when utilizing the triangular membership function (Figure 2) compared to other functions, such as z-shape, trapezoidal, s-shape, sigmoid, and Gaussian. Consequently, the triangular membership function was implemented in this study.

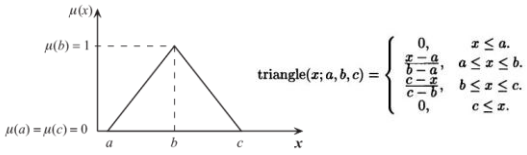

FIGURE II. THE TRIANGULAR MEMBERSHIP FUNCTION

Fuzzy Rules and Inference Engine

In this study, the Mamdani fuzzy inference system was used, and nine fuzzy rules based on expert knowledge were utilized (Table 3). An example of fuzzy rules (if-then) is presented below:

If GI is high and calories is high then gameresult is very bad

TABLE III. THE FUZZY RULES

Glycemic Index / calorie	High	Moderate	Low
High	very bad	bad	moderate
Moderate	very bad	moderate	good
Low	bad	moderate	very good

The inputs were applied to the function using the fuzzy inference engine, and the membership degree was determined. In the next step, the outputs were aggregated. There are different aggregation methods, the most important of which are maximization and summation, which were used in this study. The reason for using it is that in the maximization method, the rule with the maximum value is considered, and the rest of the rules are ignored. Therefore, the goal in this section was to emphasize the cases that the player chose; for example, if, along the way, he decided most of the low-sugar and low-calorie ingredients, then this result is obtained in maximization.

There are different methods for defuzzification. This study used the mean of maximum (mom) method (average of the maximum value of the fuzzy set). For example, If the average GI is 30 and the average food calories is 60, the fuzzy output (defuzzification) will be 87.5, which would be in the good category (Figure 3).

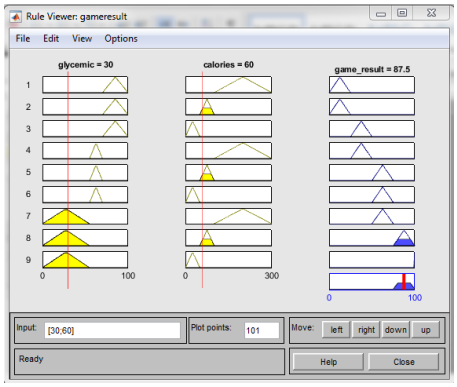

FIGURE III. THE OUTPUT OF THE FUZZY MODEL

Game Design

The Diabetic Amoo was initially designed and tested in MATLAB 2018 using a fuzzy model. It was then converted to C# in Visual Studio and implemented in the Unity environment. Diabetic Amoo was coded into seven classes, which are:

MenuUI.cs, SetupGamemode.cs, PlayerControll.cs, ObsticlesInstante.cs, Game.UI.cs, PlayerScore.cs, Triangle.cs

MenuUI.cs: This class was designed to define buttons like Start, Exit, and Music.

SetupGamemode.cs: When the player presses the start button, they enter this section, which determines the player's current state. Two states are defined: State 1 and State 2. When the player enters this section from the menu, they are in State 1, where ingredients with low, medium, and high glycemic indices (GI) are displayed. State 2 occurs after the first episode is completed, during which three ingredients with different GIs and calories are presented to the player.

PlayerControll.cs: It is used to control the player's running and jumping.

ObsticlesInstante.cs: This class was responsible for generating food items that would randomly appear for the player.

Game.UI.cs: It is related to the stop and continue buttons.

Triangle.cs:The triangular membership function is coded in this section, which is also required to retain the results from the second episode of the game.

PlayerScore.cs: The results (scores) of the first and second episodes of the game were defined in this section. For example, calculating to determine whether the player selected the correct food item or not.

RESULTS

The Diabetic Amoo was developed in Persian to run on a smartphone powered by Android. The icon of the game and the start page are displayed in Figures 4 & 5, respectively.

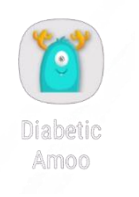

FIGURE IV. THE ICON OF THE GAME

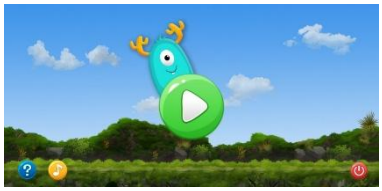

FIGURE V. THE FIRST PAGE OF THE GAME

Episode One - Glycemic Index Training

Before the first episode began, players learned that out of three food options, two had a high GI (red underline), and one had a low GI (green underline). Players had to select the food with a low GI during the first episode to win (see Figure 6).

FIGURE VI. THE GLYCEMIC INDEX TRAINING PAGE

Foods with a red underline have a high GI, and the green underline indicates a low GI.

By tapping the mobile screen, the player jumped to select the food. The player had to choose six low-GI foods to complete the first episode, as shown in Figure 7. Successfully selecting the correct foods unlocked a congratulatory message at the end of the episode (see Figure 8), allowing the player to proceed to the next episode. If the player failed to select the correct foods, they received a failure message (Figure 9) and had to repeat the episode.

FIGURE VII. THE FIRST EPISODE

FIGURE VIII. THE END OF THE FIRST EPISODE AND CONGRATULATORY MESSAGE

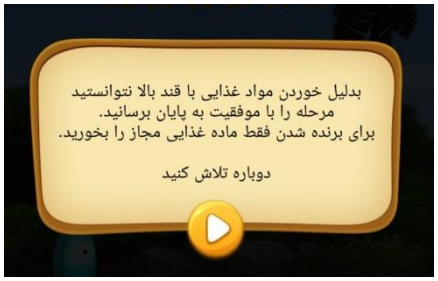

FIGURE IX. THE MESSAGE OF FAILURE TO COMPLETE THE FIRST EPISODE AND TRYING AGAIN

Episode two - Glycemic Index and food calories Training

At the beginning of the second episode, a food education segment focused on calories and glycemic index was presented. Three different foods were displayed, each accompanied by information about their calorie content and glycemic index. Foods deemed suitable were marked with a green underline, while those considered unsuitable were marked with a red underline (Figure 10). The game continued as in episode one, and at the end, the results were displayed to the player with options: very bad, bad, average, good, and very good (Figure 11).

FIGURE X. THE GLYCEMIC INDEX AND CALORIES TRAINING PAGE

Foods with a red underline have a high GI and calorie, and the green underline indicates a low GI and calorie.

FIGURE XI. THE RESULT PAGE OF THE GAME
The results can range from very bad, bad, average, good, and very good

DISCUSSION

Diabetic Amoo is a mobile-based educational game developed by a researcher in Persian using fuzzy logic, an AI technique. The game was designed to teach type 2 diabetic patients about the calorie and glycemic index of foods. A study showed that the implementation of Diabetic Amoo had a positive effect on self-management of type 2 diabetes (19). Moreover, the model utilized for developing serious games for diabetic patients has not been extensively discussed in many studies (20-27). However, the Diabetic Amoo game leverages the advantages of fuzzy logic, which are detailed below:

- Fuzzy logic is a popular choice in game development due to its resemblance to human language, making it easy to implement and understand.
- Its foundation in Boolean logic and straightforward nature makes it accessible to developers without extensive AI expertise.
- Fuzzy logic allows game developers to directly translate their expert knowledge into game rules, streamlining the development process.
- It enables the creation of non-linear and unpredictable behaviors within the game by flexibly modeling input-output relationships.
- Unlike traditional methods, fuzzy logic allows for smoother transitions between game states, resulting in more natural and realistic AI behavior.
- The flexibility of fuzzy logic makes it easy to modify and expand game rules without major code changes.
- Fuzzy logic offers a balance of complex behavior modeling with low computational cost, a crucial advantage for real-time game performance.
- This simplicity and efficiency have contributed to the widespread adoption of fuzzy logic within the game industry.

- By leveraging fuzzy logic, developers can create more intelligent, responsive, and engaging game experiences for players.
- The ability to model human-like decision-making and behavior using fuzzy logic adds a layer of realism and sophistication to games.

The advantages of using fuzzy logic in game development have often resulted in commercial success. For instance, "The Sims" remains the best-selling PC game in history, which suggests that fuzzy logic contributed to its success.

CONCLUSION

This study highlighted the positive impact of the Diabetics Amoo game, which places a strong emphasis on patient education, in significantly boosting individuals' motivation for self-care and encouraging adherence to their diabetes treatment plans. The research findings further suggest that games designed with fuzzy logic principles could be employed to effectively manage a diverse array of diseases and health conditions. Utilizing the fuzzy model in the development of serious games offers numerous benefits, particularly in the medical sector, as it allows for personalized approaches that can adapt to the varying needs of patients. This innovative strategy opens up exciting possibilities for improving health outcomes through engaging and interactive educational tools.

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CONTRIBUTORSHIP STATEMENT

A.H. conceived of the idea. M.K. developed and designed the study. Z.K. and M.K. performed the experiments and collected data. Z.K. and A.H. analyzed the data. M.K. verified the results. All authors discussed the results. Z.K. wrote the first draft with contributions from A.H. All authors reviewed and commented on the manuscript, and all are responsible for its content.

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DECLARATION OF CONFLICTING INTERESTS

The authors declared no conflicts of interest regarding the research, authorship, and publication of this article.

DATA AVAILABILITY STATEMENTS

The data will be made available from the corresponding author on reasonable request.

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