Web-Based Expert System Design and Implementation for Personal Nutrition Planning

Ceyda ÜNAL[1]
Cihan ÇILGIN[2]

DOI:10.33461/uybisbbd.1013012

Article Info

Paper Type:
Research Paper

Received:
21.10.2021

Accepted:
02.02.2022

Abstract

Recently, expert systems have been used in different fields for different purposes in order to respond to the changing user needs with the rapid development of information and communication technologies. The most important of these can be listed as interpretation, prediction, diagnosis, design, planning, imaging, debugging, maintenance, education and control. With the increase in the use of expert systems in the field of healthcare, expert systems are not only used for diagnosis and treatment, but also act as a decision support system. Today, there are many software and approaches for nutrition program planning on the basis of nutrition-oriented practices. In particular, rule-based or case-based expert systems are frequently used in the field of nutrition. The aim of the research is to develop a web-based expert system prototype in the field of nutrition with a rule-based system approach using the Prolog development environment. For this purpose, because of clear and neat syntax, one of the expert system programming languages based on "first order predicate calculus" that is Prolog, PHP for web and in the design phase; Bootstrap framework were preferred. For data visualization, data is retrieved from MySQL database. The application developed within the scope of the research is expected to contribute to the efficient implementation of nutrition planning, especially for institutions with insufficient human experts. In this sense, a system that offers personalized nutrition program recommendations for people of different ages, genders, heights, weights and therefore different body mass indexes has been developed. Thus, considering the benefits of proper nutrition, it is expected that the developed system will help the dietitian in the process of determining the nutrition program/meal planning, and for the patients in the processes of maintaining and monitoring it.

***Keywords**: expert systems, Prolog, nutrition program, meal planning.*

Atıf/ to Cite (APA): Ünal, C., and Çılgın, C., (2022). Web-Based Expert System Design and Implementation for Personal Nutrition Planning. International Journal of Management Information Systems and Computer Science, 6(1), 1-12

[1] Res. Asst., Dokuz Eylul University, Department of Management Information Systems, ceyda.unal@deu.edu.tr, İzmir, Türkiye.
[2] Res.Asst., Bolu Abant İzzet Baysal University, Department of Management Information Systems, cihancilgin@ibu.edu.tr, Bolu, Türkiye

1. INTRODUCTION

Nutrition is a science (Whitney & Rolfes, 2018). Health and nutrition are important as goals and often emerge as critical components of basic needs in developing countries (Behrman & Deolalikar, 1988). Food or nutrition provides the basic components needed to maintain daily activities (Ojokoh & Babalola, 2016). Nutrition is the act of taking the nutrients needed by the body in sufficient quantities and at appropriate times in order to protect, improve health and the quality of life. It also includes the environmental, psychological and behavioral aspects of food and the act of eating (Turkish Ministry of Health, Directorate General of Public Health, 2017). Nutrition focuses on how to protect the body from diseases through healthy nutrition. While proper nutrition provides benefits to individuals in this sense, malnutrition has harms such as sensory changes (taste, smell, eye sight), poor dental health, and physical ailments. (Merrell et al., 2012). Nutrients obtained through nutrition provide the person with the energy needed to perform different activities in daily life and help the body prevent diseases (Hazman & Idrees, 2015). People decide what to eat and when to eat in highly personal ways, acting on behavioral or social motives rather than awareness of the importance of nutrition for health. While the preferred food choice can support health, understanding or planning nutrition helps people make rational choices more often (Whitney & Rolfes, 2018). Although the World Health Organization has recently identified the general increase in non-communicable diseases (such as early heart diseases, diabetes and cancer) as a major problem, malnutrition has been identified as an important factor causing such diseases. In this context, personalized nutrition is emerging as a new research area to provide personalized food intake recommendations to individuals based on their physical, physiological data and more personal information (Toledo et al., 2019). In particular, advancements in information and communication technologies lead individuals and institutions to apply different artificial intelligence technologies for decision-making purposes. Expert systems, one of them, aim to transfer expert knowledge to computer software through various rules. Therefore, it would not be wrong to say that the use of this technology in the field of nutrition will add value to human life. The expert system, which automates the nutrition program, helps individuals evaluate their nutritional status/conditions and offers them nutritional recommendations accordingly. At the same time, expert systems on nutrition have become an important issue that has attracted the attention of researchers in recent years and different studies have been carried out on this subject. As people become more health literate today, the need for a system that can measure calories and nutrition in daily meals or make meal recommendations is increasing in order to consume healthier foods and avoid fast food. Such systems are very useful for dietitians and patients to measure as well as manage their daily food intake (Mustafa et al., 2020). A nutrition expert system can help individuals evaluate their nutritional plans and conditions and provide recommendations accordingly. It will also help people save time as they will not need to go to the doctor to evaluate their nutritional status (Al-Dhuhli et al., 2013). This research article aims to develop a web-based expert system prototype in the field of nutrition with a rule-based system approach using the Prolog development environment. The web-based recommendation system developed for this purpose allows dietitians to create personalized nutrition programs and to follow these programs. It also speeds up the whole process. In addition, within the scope of the accessible literature, it is aimed to design the nutrition program recommendation system for the use of dietitians rather than the use of patients who are the end users. The expert system developed within this framework will facilitate the dietitian's meal programming task and speed up the process. Besides that, to the best of our knowledge; it presents the first rule-based expert system design for Turkish food habits.

In the following part of the research, literature on nutrition and diet recommendation systems are included. Then, a conceptual analysis of expert systems and implementation phase was reported. While the last part of the research is the conclusion part, suggestions for future studies are also presented in this section.

2. RELATED WORKS

Expert systems have been successfully applied in many fields of researches since the 1970s. Following the emergence of expert systems in medicine as an exciting area of research that promises to revolutionize medical practice (Heathfield, 1990), these systems have been used in many applications. In order to cope with complex problems, expert systems were first introduced as a sub-branch of artificial intelligence to be used in disease diagnosis problems in the medical field. Today, many expert systems such as MYCIN, PUFF, DXplain, HELP and Hepaxpert (Metaxiotis & Samouilidis, 2000) are used in diagnosis, monitoring, analysis, consultation, planning, explanation, education, narration, giving ideas and many more. Expert systems reveals structures that bring together different disciplines. The use of expert systems, especially in the field of healthcare, is increasing day by day. In recent years, the increase in the use of expert systems, especially in the field of nutrition and dietetics, is striking. In this sense, many researchers have studied the use of expert systems in the field of nutrition. (Kovasznai, 2011; Chen et al., 2012; Ma'aruf & Garba, 2012; Al-Dhuhli et al., 2013; Merwe et al., 2014; Cioara et al., 2018), has contributed to the literature.

Kovasznai (2011) introduced a case-based approach to dietary recommendations in their study. Based on this approach, an expert system was designed to be used in the health record management system. For this, "Ripple-down", one of the rule-based learning algorithms, was preferred. Using ripple-down, the object space (i.e. the sum of all object classes) is progressively divided into smaller and smaller partitions. The goal is to classify all objects from the same class into the same partition. As a result of the research, it was observed that the approach of using ripple-down and appropriate rule notation is valid in the health record management system.

Chen et al. (2012) presented a research to design a web-based expert system for nutritional diagnosis using expert system techniques in the field of artificial intelligence. Within the scope of the research, the Nutritional Care Process and Model, which was defined by the American Dietetic Association in 2008, was applied and the nutritional diagnosis information of dietetics experts was integrated into the system to form the basis of establishing the knowledge base. The system was built using Microsoft Visual Studio 2008 on the .NET Framework 3.5SP1, using the built-in rules engine that comes with Windows Workflow Foundation. Thanks to the developed system; dietetic specialists are able to enter the patient's basic data, anthropometric data, physical examination findings, biochemical data and food / nutrition history into the program. At the same time, after the dietetic specialists completed the nutritional assessment, the program rule base could be inferred and a nutritional diagnosis could be made. In order to carry out the research, 100 chronic kidney patients under hemodialysis were selected from a university hospital, albumin, cholesterol, creatinine, height and dry weight of the patients before dialysis were recorded, and then these data were used for both expert system and nutritional diagnosis. When the results are compared, it has been observed that the expert system gives faster and more accurate results than the human dietitian.

In the "Expert Diet Prescription System" they developed, Ma'aruf and Garba (2012) presented a result that defines a disease according to the name or symptoms and recommends the appropriate diet corresponding to this disease. The system has three levels of access to the database: patient, doctor and administrator. For this, a database of seven known diseases such as cancer, diabetes, measles, cholera, malaria, goiter and enlarged heart disease was created, using information from experts. Wamp server, PHP and MySQL and code editor were used to design the database, interface and graphics of the system. It has been emphasized that it is very necessary to implement the expert diet system, especially because of the long-term destructive effect of drugs as a result of drug addiction or the reaction to certain diseases in exceptional cases.

Al-Dhuhli et al. (2013) aimed to develop an expert system prototype in the field of nutrition by using the rule-based system technique in their article. The knowledge engineering process was completed by gaining knowledge from experts in the field from the nutrition department at a local university and from expert-recommended websites. The logic of the expert system is organized into

inputs – middle part (via if-then statements and decision tables) and outputs. In addition, after the nutrition and diet prototype expert system was developed, the system was validated by the experts. Additionally, the system has been tested by potential users to evaluate its benefits and limitations. As a result, users identified various benefits of the developed expert system and proposed the prototype. Similarly, Gupta and Bhattacharjee (2018) focus on the process of developing the Diet and Nutrition Expert System prototype and the potential benefits of developing this system.

Merwe et al. (2014) designed an expert system to solve multiple aspects of the diet problem by creating a rule-based inference engine consisting of goal programming and multi-objective linear programming models. The program was supported by case studies specific to South African girls from the knowledge acquisition phase. As a result of this, system creates a meal plan for a girl that fits the nutritional requirements of a healthy diet, incorporates personal food preferences, and features food items that provide the lowest total cost. The system also allows for prioritization of food preferences.

Cioara et al. (2018) presented an expert system for the nutritional care process tailored to the special needs of the elderly. Dietary knowledge was defined by nutritionists and designed as "Nutrition Care Process Ontology" and then used as a knowledge base for nutritional care planning. Also on top of ontology, an inference engine has been developed to assess the short- and long-term nutritional behavior of the elderly, identify unhealthy eating patterns, and detect early imbalance of malnutrition. The developed expert system offers personalized intervention plans covering nutrition education, diet prescription and food ordering tailored to the specific nutritional needs, health conditions and food preferences of older adults. In-laboratory evaluation results are evidenced by the computational efficiency, effectiveness and coherence of the defined ontology as well as the use and quality of the expert system. The presentation of a nutrition and diet expert system via web or mobile applications are frequently used platforms in this field, as in the work of Hong & Kim (2005).

In this research, unlike the literature, it is aimed to design the nutrition program recommendation system for the use of dietitians rather than the use of end-user patients. The expert system developed within this framework will facilitate the meal programming tasks of dietitians and accelerate the process. Supporting patient follow-up, informing and management with user-friendly interfaces with the web technologies used is one of the advantages offered by the system. In addition, within the scope of the accessible literature, the first rule-based expert system design for Turkish food habits is presented by this study.

3. EXPERT SYSTEMS

Expert system technology is the first real commercial application of research and development in the field of artificial intelligence (Rajeev & Krishnamoorthy, 1996). Expert systems are one of the practical and successful areas of artificial intelligence. They are used in many areas where detailed information is needed for a particular problem. At the same time, they are useful systems when there is a shortage of human experts in a specific field (Nowak & Szewczyk, 2021). Expert systems are accepted as one of the first practical application areas of artificial intelligence (AI) in the business world in recent years. Many applications of expert system technology have been used frequently in the fields of medicine and engineering, as well as management and finance (Lu & Guimaraes, 1989). Most of the existing expert systems consist of rule-based systems that require a difficult and time-consuming knowledge acquisition process, and in this process, expertise is allocated from experts. In addition, regular updating of the knowledge base in the system is considered a critical requirement (Lu & Lu, 1992). Although the development of expert systems is not a simple process, it demands a lot of time and effort. Obtaining the necessary information, especially from the experts, compiling them and making them transferable to the computer are seen as the most important problems in expert system design (Allahverdi, 2002). In order to design these systems, system components must be analyzed effectively and efficiently at every step. These components consist of a number of main

system components, individuals and interfaces in various roles and are summarized below (Merritt, 2012: 2):

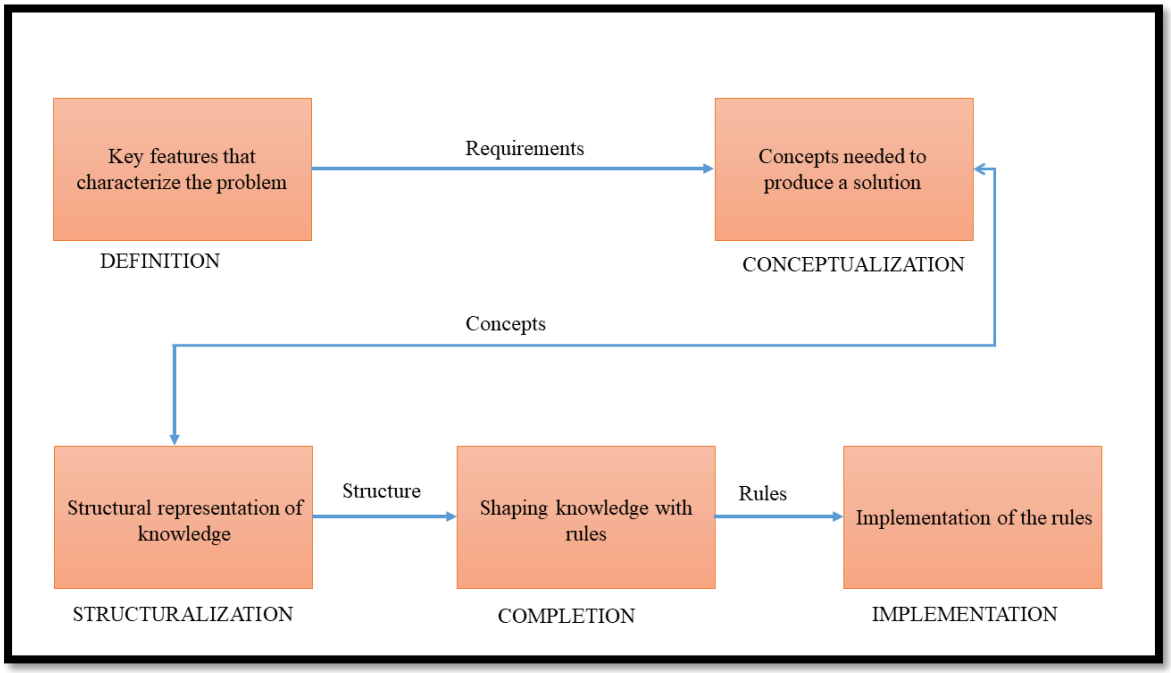
- **Knowledge base:** A rule-based representation of expert knowledge, usually consisting of an IF THEN rule structure
- **Working storage:** Data specific to a problem or issue
- **Inference engine:** The underlying code of the system that derives recommendations from the knowledge base and problem-specific data in working memory
- **User interface:** Structure that provides and controls the communication between system in which the user and expert information takes place.

At the present time, medical expert systems are computer software that assist doctors in evaluating and monitoring patients, diagnosing and treating problems. Medical expert systems are a type of computer-assisted artificial intelligence that helps doctors, nurses and general practitioners make informed, accurate and reliable decisions about the management of patient processes (Cioara et al., 2018). Similarly, expert systems, which are increasingly being used in the fields in nutrition programs and dietetics, constitute the main point of this research.

4. METHODOLOGY

The application developed within the scope of this study basically consists of two stages. The first part is an inference engine developed with Prolog, which includes rules created from various nutritional values and BMI (Body Mass Index). The second part is a Web-based interface environment that practitioners will use both to manage patient processes and to create a nutrition plan through the expert system. Throughout the development of the inference engine via Prolog, the process steps in Figure 1 were followed.

Figure 1: Expert System Development Process (İçen & Günay, 2014).



First of all, the important features of the problem were determined as a result of the interviews with the nutrition and dietetics specialist in the definition step. For this purpose, information was obtained through face-to-face interviews with two different dietitians who are experts in their fields. In addition, the information received from each dietitian was cross-checked by the other dietitian in terms of accuracy and reliability. As a result of this process, the necessary documentation for both conceptualization and knowledge rules has been made. In the conceptualization step, the necessary patterns and concepts to solve the problem are decided. In the structuralization step, it was decided that the existing knowledge would be represented by the Prolog expert system programming language. The reason is that Prolog can be considered as a logic programming language and has a crucial role in artificial intelligence. Unlike many other programming languages, Prolog is intended mainly as a declarative programming language. It is also based on facts and rules. In the completion step, the information collected was organized and alternative ways to solve the problem were determined. At this stage, the "backtracking" method was used. Backtracking, also called backtracking algorithm, is the name of the algorithm used in computer science to search for a value or reach a goal. There must be a purpose here and a right choice must be sought among the various ways to reach the aim. In the implementation step, necessary regularizations were made as a result of the problems encountered in the problem discussed. For this purpose, facts, rules and predicates were created in Prolog language and the knowledge base was designed in this way.

5. SYSTEM IMPLEMENTATION

In the system implementation process, firstly, the facts created with the name of "food", the maximum amount of food to be consumed in a meal, the name of the food, calories, carbohydrates, proteins and fats are added to the knowledge base by the expert system as seen in Figure 2. Here, “kv” represents breakfast, “ara” represents snack, “og” represents lunch and “ak” represents dinner. Foods are grouped according to which meals they will be preferred. For example, fat-free white cheese can be consumed only for breakfast, while dried apricots are a food that can be consumed together for breakfast and snacks. Values such as carbohydrates, protein and fat were calculated on the basis of grams. BMI is calculated according to the entered values. BMI value differs according to gender. Accordingly, daily total calories, daily total carbohydrates, daily total protein and daily total fat were calculated on the basis of the person created, and a suitable nutrition plan was prepared for that person. For this purpose, the BMI value of the person is calculated as a fact in line with the information of the person entered into the system. Then, how much less calorie amount will be than the calorie amount that should be taken daily is entered into the system. Thus, meals can be determined on the basis of four basic rules. The first rule was created for the amount of calories to be taken daily, and for this purpose, it reveals how many calories should be taken from which meals. In order to be more descriptive, the rule for the total daily calorie amount is given below.

Daily_total_cal(Cal,[Breakfast,Snack1,Lunch,Dinner,Snack3]):-
*Breakfast is 0.2 * Cal, Snack1 is 0.0666 * Cal, Lunch is 0.3 * Cal, Snack2 is 0.0666 * Cal, Dinner is 0.3 * Cal, Snack3 is 0.0666 * Cal.*

Figure 2: Rules in Knowledge-base

diet.pl

File Edit Browse Compile Prolog Pce Help

diet.pl

```
:- dynamic kisi/6.
numbers([1,2,3,4,5,6,7,8,9,10]).

% besin(Id,Maksimum miktar,[Tür],Besin, kalori, Karb(g), Pro(g),
%% yağ(g))
besin(1,3,[kv,ara],'Yumurta',193,0.83,13.61,14.84).
besin(2,1,[kv,ara],'Bir kase(50g) yulaf ezmesi - Sekersiz',158, 27, 6, 3.2).
besin(3,1,[kv],'100g Hazir kahvaltilik Kinoa',392, 62.80, 14.50, 2.4).
besin(4,2,[kv],'1 Dilim(25g) Kepekli Ekmek',54, 11.14, 1.51, 0.38).
besin(5,2,[kv],'1 Dilim(30g) Yagsiz Beyaz Peynir',56, 1.8, 8.5, 2.3).
besin(6,2,[kv,ara],'1 Porsiyon(40g) Kuru Et',104, 1.92, 18.4, 2.52).
besin(7,2,[kv,ara],'1 Porsiyon(50g) Cemensiz Pastirma',95, 2, 16, 2.5).
besin(8,3,[kv],'1 Porsiyon(20g) Zeytin',41, 0.2, 0.4, 4.2).
%besin(9,3,[ara],'1 Bardak Sade Kahve - Şekersiz',0, 0, 0,0).
%besin(10,1,[kv],'1 Bardak(250ml) Sebze Smoothie',53, 5.2, 3, 2.8).
besin(11,1,[kv, ara],'Elma (orta)',52, 13.81, 0.26, 0.17).
besin(12,1,[kv, ara],'Muz (orta)',151, 38.83, 1.85, 0.56).
besin(13,1,[kv, ara],'Greyfurt',100, 8.9, 0.6, 0.1).
besin(14,1,[kv, ara],'Ananas (100g)',50, 13, 0.5, 0.1).
besin(15,1,[kv, ara],'Havuc (orta)',16, 3.83, 0.37, 0.1).
besin(16,2,[ara],'Salatalik (orta)',18, 4.3, 0.78, 0.13).
besin(17,2,[ara],'Protein Bar (80g)', 120, 10.56, 3.5, 7.26).
besin(18,1,[ara],'Bir Avuc Ceviz (25g)',151, 2.4, 6.02, 14.83).
besin(19,1,[ara],'Bir Avuc Findik (25g)',151, 4.01,3.59, 14.58).
besin(20,1,[ara],'Bir Avuc Badem (25g)',143, 0.93, 4.68, 13.53).
besin(21,1,[kv, ara],'Bir kase Yogurt (180g)',110, 8.39, 6.25, 5.85).
besin(22,1,[ara],'Bir paket Form Diyet Bisküvi',184, 26.69, 5.9, 4.86).
besin(23,1,[ara],'Bir Avuc Leblebi(25g)',60, 8, 4.25, 0.75).
besin(24,2,[kv, ara],'2 Adet Kuru Kay.',50, 12.03, 1.5, 0.25).
besin(25,1,[kv, ara],'2 Adet Kuru Incir',100, 25.4, 1.26, 0.38).
besin(26,1,[og, ak],'1 Porsiyon (80gr) Kir. et, az yagli',125, 0, 22.3, 4).
besin(27,1,[og, ak],'1 Porsiyon (100gr) Ton baligi',174, 0, 17.3,12).
```

Afterwards, separate rules were established for the total amount of carbohydrates, proteins and fats that should be taken at all meals. Nutrition alternatives including all possible situations are derived by using the "backtracking" method together with the rules created. For example, all options that may occur for breakfast are obtained by the "backtracking" method, and various alternatives related to the food group compatible with the same calorie, carbohydrate, fat and protein values are presented as system output as seen in Figure 3. At this point, all these meal alternatives can be used as alternatives in the range of calorie, carbohydrate, fat and protein values set as a result of personally determined characteristics.

Figure 3: Outputs Generated by the System

SWI-Prolog (AMD64, Multi-threaded, version 8.0.3)

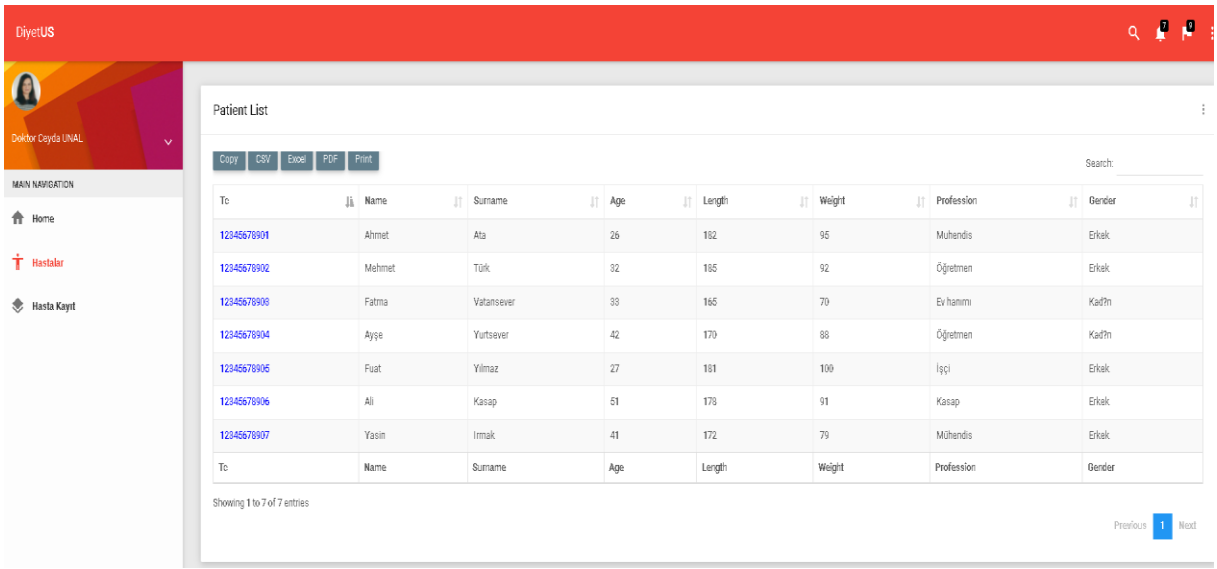
File Edit Settings Run Debug Help

```
[[24,2 Adet Kuru Kay.,1],[8,1 Porsiyon(20g) Zeytin,1],[24,2 Adet Kuru Kay.,1]]
[[24,2 Adet Kuru Kay.,1],[8,1 Porsiyon(20g) Zeytin,2]]
[[24,2 Adet Kuru Kay.,1],[8,1 Porsiyon(20g) Zeytin,3]]
[[24,2 Adet Kuru Kay.,1],[11,Elma (orta),1]]
[[24,2 Adet Kuru Kay.,1],[13,Greyfurt,1]]
[[24,2 Adet Kuru Kay.,1],[14,Ananas (100g),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[1,Yumurta,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[4,1 Dilim(25g) Kepekli Ekmek,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[5,1 Dilim(30g) Yagsiz Beyaz Peynir,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[5,1 Dilim(30g) Yagsiz Beyaz Peynir,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[6,1 Porsiyon(40g) Kuru Et,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[6,1 Porsiyon(40g) Kuru Et,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[7,1 Porsiyon(50g) Cemensiz Pastirma,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[7,1 Porsiyon(50g) Cemensiz Pastirma,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,3]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[11,Elma (orta),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[13,Greyfurt,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[14,Ananas (100g),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[1,Yumurta,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[4,1 Dilim(25g) Kepekli Ekmek,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[5,1 Dilim(30g) Yagsiz Beyaz Peynir,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[5,1 Dilim(30g) Yagsiz Beyaz Peynir,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[6,1 Porsiyon(40g) Kuru Et,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[7,1 Porsiyon(50g) Cemensiz Pastirma,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[7,1 Porsiyon(50g) Cemensiz Pastirma,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,2]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[8,1 Porsiyon(20g) Zeytin,3]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[12,Greyfurt,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[15,Havuc (orta),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[15,Havuc (orta),1],[15,Havuc (orta),1],[21,Bir kase Yogurt (180g),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[21,Bir kase Yogurt (180g),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[24,2 Adet Kuru Kay.,1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[21,Bir kase Yogurt (180g),1]]
[[24,2 Adet Kuru Kay.,1],[15,Havuc (orta),1],[24,2 Adet Kuru Kay.,1]]
[[24,2 Adet Kuru Kay.,1],[21,Bir kase Yogurt (180g),1]]
[[24,2 Adet Kuru Kay.,1],[24,2 Adet Kuru Kay.,1]]
[[24,2 Adet Kuru Kay.,2]]
[[25,2 Adet Kuru Incir,1]]
false.
```

In the second step of the application, these values from Prolog were both displayed on the web and it was possible to monitor the process with data visualization. A web interface has been developed for this. At this stage, PHP programming language and Bootstrap framework were used. With the

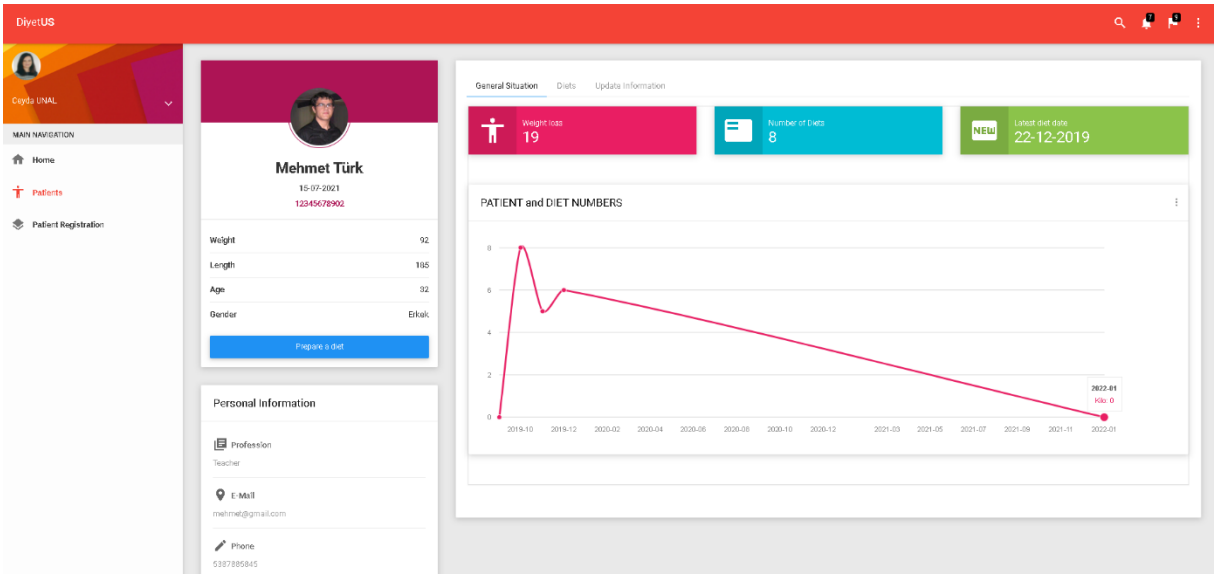
developed interface, the user who enters the system as a doctor can register patients and view the patient list. On the patient registration screen, there are fields for ID number, name, surname, age, height, weight, telephone, e-mail, profession, photo and gender. The authorized user, who records all these in the system, can view his patients as in Figure 4. List entries can also be copied, converted to CSV, Excel and PDF formats and printed.

Figure 4: Patient List Screen



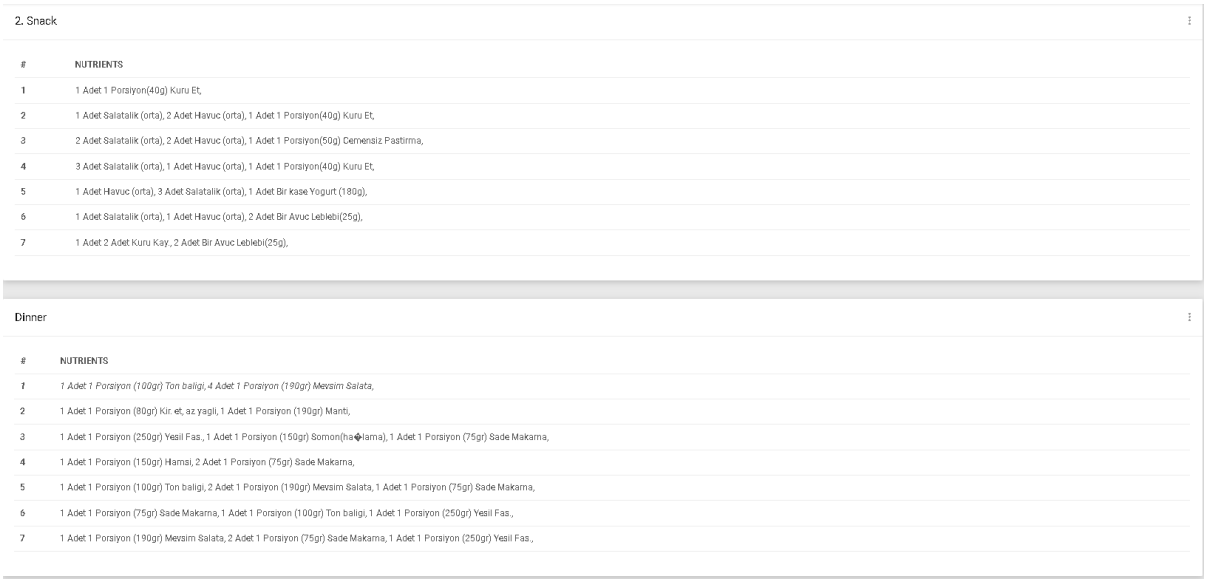
For example, it is sufficient to reach the ID number of the patient to view the profile of any patient and to access detailed information about the nutrition program. In this case, the patient profile can be seen as in Figure 5. On this screen, the patient's weight, height, age, gender, personal information, and the general status of the patient regarding the nutrition program (weight loss, number of programs, last written date) can be displayed. If desired, patient information can be updated. The reason why information such as gender, height and weight is taken from a separate form instead of taking the information from Prolog and preparing a nutrition program according to it can be summarized as the fact that there are too many alternatives and the hardware and software problems caused by running these alternatives one by one each time. In this way, progress was made in a systematic way, instead of taking too much action to identify suitable alternatives each time. As seen in Figure 3, each backtrack step puts the system in trouble even in a single meal.

Figure 5: Patient Profile



When the "Prepare Nutrition Program" option is selected in the patient profile, the patient is asked about the amount of calories that should be reduced from the daily calories. Then, as a result of the information obtained from here, the inference mechanism created by using the knowledge and rule base and the meal list created by the expert system as seen in Figure 6 are presented. Although the output for two meals is displayed in Figure 6, only the output information of these two meals is presented for ease of display, and the entire nutrition program created by the system for six different meals and seven days of the week can be viewed by this interface.

Figure 6: Nutrition Program Generated by the Expert System



After the nutrition program is created, it is also possible to save the diet list. In addition, by clicking on the meal list for each day, a more suitable meal list can be selected by switching to the alternative lists created by the expert system for that meal. The point to be noted here is that if the patient's height and weight is high and the age is small, the execution time will increase in direct proportion to this, since the BMI value will be high. In summary, it takes longer to evaluate alternatives. In addition, the Dashboard screens presented with the developed interface screen provide an overview of the experts for patients and nutrition programs. From here, users can view data such

as the number of patients, the number of nutritional recommendations, the number of new patients, and they can monitor the patient-nutrition quantitites with the help of visual tools. Thus, the process becomes more transparent and traceable. These structures can help to monitor different policies in the context of workload, especially in large and institutional chain hospitals, and also bring along a follow-up and registration system in order to use the positive results obtained with the nutrition programs implemented in the past for future patients.

6. CONCLUSION

In today's world, where the interest in the applications of expert systems in different fields is increasing day by day, there are various advantages of using the information obtained from the experts for different purposes on a rule-based basis. Especially in the field of healthcare, it has gained a different dimension with the use of artificial intelligence, which is one of the Industry 4.0 technologies, to be effective in different processes. When expert systems are considered as a sub-branch of artificial intelligence, developed in the field of nutrition have begun to evolve towards automated systems dominated by technology. The role of healthy nutrition in the context of protecting health, preventing diseases and increasing the quality of life is undeniable. Especially in recent years, the critical importance of healthy nutrition is being understood more. Thus, more and more individuals are trying to gain awareness on how to eat healthier. Expert systems, on the other hand, can help individuals to increase this awareness and get appropriate advice from experts. It is thought that these new application areas will support the concept of expert systems and this approach will reveal wider application areas in the next few years. The application developed within the scope of the research is expected to contribute to the efficient realization of meal planning, especially for regions where there are not enough specialists, to speed up the remote follow-up processes of the nutrition program, and to make appropriate revisions in the nutrition program by acting as a decision support system for experts.

Although the researches in the literature (Kovasznai, 2011; Chen et al., 2012; Ma'aruf & Garba, 2012; Gupta & Bhattacharjee, 2018) are generally aimed at end users who want to create a nutrition plan, the main purpose of this research is to provide a practical output to speed up the of expert dietitians in the process of creating a nutrition plan. In addition, many of the systems developed for nutrition planning are designed according to pre-determined information rules and are quite static systems. On the contrary, each dietitian can create new information rules as well as entering new nutrients through the system proposed in this research. In fact, they can create a collective environment by sharing the diet plans, nutrients and diet outputs they have created for their patients with other dietitians within the system. Thus, nutrition plans that have achieved better results for similar situations can be used for different patients. In this context, unlike other researches, the system developed in this research is not only an expert system on its own, but can also be used as a collaboration tool.

In this sense, a system that offers personalized nutrition program recommendations for people of different ages, genders, heights, weights and therefore different body mass indexes has been developed. The web-based expert system consists of the rules and facts presented by Prolog. However, the inference engine offers the appropriate food combinations to the expert's use instantly via the backtracking method. In addition, it integrates expert knowledge into the system by making various correct nutrition recommendations. Thus, considering the benefits of proper nutrition, it is expected that the developed system will help the dietitian in the process of determining the nutrition program/meal planning, and for the patients in the processes of maintaining and monitoring it. Within the scope of the research, the expert system-based application is at the prototype stage and has not yet been integrated into an online system. It is used by field experts for testing when necessary. In future studies, a wider framework with different food groups can be put forward, and additional researches can be made about foods that should not be consumed at the same time.

REFERENCES

Al-Dhuhli, B. A., Al-Gadidi, B. S., Al-Alawi, H. H., Al-Busaidi, K. A. (2013, June). Developing a Nutrition and Diet Expert System Prototype. In *21st International Business Information Management Association Conference*.

Allahverdi, N. (2002). Uzman Sistemler: Bir Yapay Zeka Uygulaması. Atlas Yayın Dağıtım. İstanbul.

Behrman, J. R., Deolalikar, A. B. (1988). "Health and Nutrition". Handbook of Development Economics, *1*, 631-711.

Chen, Y., Hsu, C. Y., Liu, L., Yang, S. (2012). "Constructing a Nutrition Diagnosis Expert System". Expert Systems with Applications, 39(2), 2132-2156.

Cioara, T., Anghel, I., Salomie, I., Barakat, L., Miles, S., Reidlinger, D., Taweel, A., Dobre, C., Pop, F. (2018). "Expert System for Nutrition Care Process of Older Adults". Future Generation Computer Systems, *80*, 368-383.

Gupta, M., Bhattacharjee, P. (2018). "DANES: Diet and Nutrition Expert System for Meal Management and Nutrition Counseling". International Journal on Recent and Innovation Trends in Computing and Communication, 5(12), 204-208.

Hazman, M., & Idrees, A. M. (2015, November). A Healthy Nutrition Expert System for Children. In *2015 E-Health and Bioengineering Conference (EHB)* (pp. 1-4). IEEE.

Heathfield, H. (1999). "The Rise And 'Fall' of Expert Systems in Medicine". Expert Systems, *16*(3), 183-188.

Hong, S. M., Kim, G. (2005). "Web Expert System for Nutrition Counseling and Menu Management". Journal of Community Nutrition, *7*(2), 107-113.

İçen, D., Günay, S. (2014). "Uzman Sistemler ve İstatistik". İstatistikçiler Dergisi: İstatistik ve Aktüerya, *7*(2), 37-45.

Kovasznai, G. (2011). Developing an Expert System for Diet Recommendation. *6th IEEE International Symposium on Applied Computational Intelligence and Informatics* IEEE. 505-509.

Lu, M. T., Lu, D. H. (1992). "Neurocomputing Approach to Residential Property Valuation". Journal of Organizational and End User Computing *(JOEUC), 4*(2), 21-30.

Lu, M., Mooney, S. P. (1989). "Assessing Expert SystemApplications: A Case Study". International Journal of Information Management, 9, 267-273.

Ma'aruf, L. M., Garba, M. (2012). "Design and Implementation of an Expert Diet Prescription System". International Journal of Artificial Intelligence and Expert Systems *(IJAE),* 3(4), 126-134.

Merrell, J., Philpin, S., Warring, J., Hobby, D., Gregory, V. (2012). "Addressing The Nutritional Needs of Older People in Residential Care Homes". Health & Social Care in the Community, *20*(2), 208-215.

Merritt, D. (2012). Building Expert Systems in Prolog. Springer Science & Business Media.

Metaxiotis, K. S., Samouilidis, J. E. (2000). "Expert Systems in Medicine: Academic Exercise or Practical Tool?". Journal of Medical Engineering & Technology, *24*(2), 68-72.

Mustafa, N., Hadi, A., Samsiah, N., Izham, M., Zawawi, A., Ahmad, A. (2020). iDietScore: Meal Recommender System for Athletes and Active Individuals. *IJACSA*, *11*, 12.

Nowak, M., Szewczyk, J. (2021). Expert Systems in Medicine. *The Book of Articles*, 84.

Ojokoh, B., Babalola, A. (2016). "A Personalized Healthy Diet Recommender System". Organization for Women in Science for the Developing World (OWSD), 388-393.

Pac, M., Mikutskaya, I., Mulawka, J. (2021). "Knowledge Discovery from Medical Data and Development of an Expert System in Immunology". Entropy, *23*(6), 695.

Rajeev, S., Krishnamoorthy, C. S. (1996). Artificial Intelligence and Expert Systems for Engineers. CRC Press.

Toledo, R. Y., Alzahrani, A. A., Martinez, L. (2019). "A Food Recommender System Considering Nutritional Information and User Preferences". *IEEE Access, 7*, 96695-96711.

Turkish Ministry of Health, Directorate General of Public Health (2017). Yeterli ve Dengeli Beslenme Nedir?. https://hsgm.saglik.gov.tr/tr/beslenme/yeterli-ve-dengeli-beslenme-nedir.html. 16.10.2021.

van der Merwe A., Kruger H., Steyn T. (2015). "A Diet Expert System Utilizing Linear Programming Models in a Rule-based Inference Engine". Journal of Applied Operational Research. 7(1):13–22.

Whitney, E., Rolfes, S. R. (2018). Understanding Nutrition. Cengage Learning.