A Hybrid Intelligence System For Assisting Individuals With Gastrointestinal Tract Diseases

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***Abstract*—Hybrid intelligent systems allow people to organize their time and simplify their day-to-day life processes related to forming a meal plan. This paper describes a method of presenting knowledge of the modern expert system, a description of the methods of the recommender system as a part of a hybrid intelligent system is given. Special attention is given to the legal regulation of intelligent systems in the area of telehealth. As a result of analyzing a number of properties of influencing people with inflammatory diseases of the digestive tract, a classified list of the main properties that affect patients with inflammatory diseases of the digestive system is highlighted. The paper presented the structure of the hybrid intelligent system for assisting people with gastrointestinal tract diseases. The paper also highlighted the main stages of designing such a system and presented the main algorithm of the system in general and of the process of forming a personalized nutrition plan. Besides, the process of making a diagnostics decision is described. A typical and alternative scenario of forming an individual nutrition plan was presented. The study considered an example of forming a nutrition plan based on the user's personal preferences. The study results are the recommendations for further development of the systems and a description of the ways of integrating the system in major telehealth services.**

I. INTRODUCTION

Mobile applications for consulting users in different health aspects are currently very widespread due to the active development of information technologies and the continuous improvement of medicine [1-11]. On the Internet, one can find applications for finding medicaments or doctors, diagnostics apps, first aid manual, and so on.

One of these areas is telehealth, where one can use remote and digital technologies to contact a doctor or specialist in the necessary field and get advice [1-5].

According to the World Health Organization (WHO) [4], chronic diseases are the leading cause of death worldwide, causing 60% of all deaths. The prevalence of chronic diseases is increasing due to lifestyle changes and preventive care access shortage. The causes of chronic diseases can range from genetic predisposition to environmental factors and oxidative stress. So, the growth of chronic diseases positively influences the growth of the telehealth market worldwide [2],[4-6], Fig. 1.

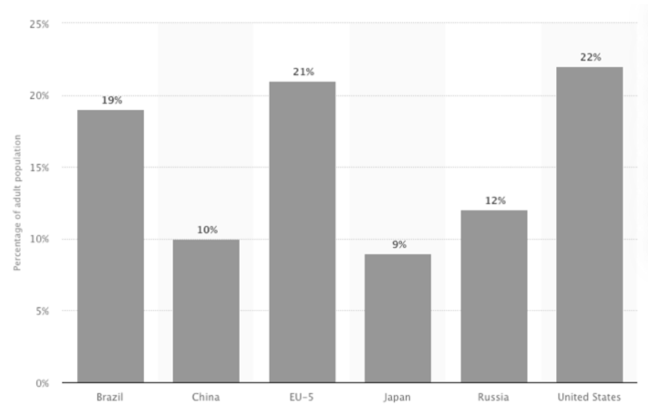

Fig. 1. Prevalence of diagnosed gastrointestinal conditions in selected countries as of 2019 [3]

According to estimates, 4.8 million new cases of gastrointestinal cancer and 3.4 million related deaths were recorded in 2018. Gastric cancer is related to 26 % of the cancers worldwide and 35% of all cancer deaths.

The statistics of the development of these diseases show that the problem of forming a meal plan for sick individuals is relevant and urgent. This problem can be solved by using a hybrid intelligent system for helping people with gastrointestinal diseases, which would allow users to create an individual meal plan based on their personal tastes, medical recommendations, diagnosis, and previous experience with other people who have similar preferences.

So, the problem of forming a meal plan for sick individuals is relevant and urgent, given these statistics. This problem can be solved with the help of a hybrid intelligent system for helping people with gastrointestinal problems, which would allow users to create an individual meal plan based on their personal tastes, doctors ' recommendations, diagnosis, and previous experience with other people who have similar preferences [1-7].

Currently, there are many systems and applications for forming diets, counting calories, planning sports nutrition. However, there is no application that would combine medical knowledge as well as the utility for making a meal plan based on personal preferences and doctor's recommendations.

II. Theoretical Research

A. *The main concept of this study are as follows*

The digestive system is a system of organs carrying out mechanical and chemical processing of food, the absorption of processed substances, and the removal of undigested and under digested components of food.

Diagnosis is recognition aimed at revealing the essence of the pedagogical phenomenon or process being studied, which is already sufficiently fully and deeply described and with which it correlates (compares) the information received.

Inflammatory bowel diseases (IBD) are a group of intestinal disorders characterized by long-term inflammation of the digestive tract. Inflammation of even one of the sections of the gastrointestinal tract disrupts the normal digestive process. Intestinal inflammation often causes severe pain and has a devastating effect on the body, and in certain cases, it can even be deadly.

Diet is a regime of nutrition of a healthy and a sick person determined by the food quality, amount (total amount and amount of ingredients), mealtime, and frequency.

Besides, an understanding of the composition of the digestive system is required for a clear understanding of its key properties. Fig. 2 shows all organs of the digestive system [7-8]. Description of functions of the digestive system and their purpose are elaborated in [6].

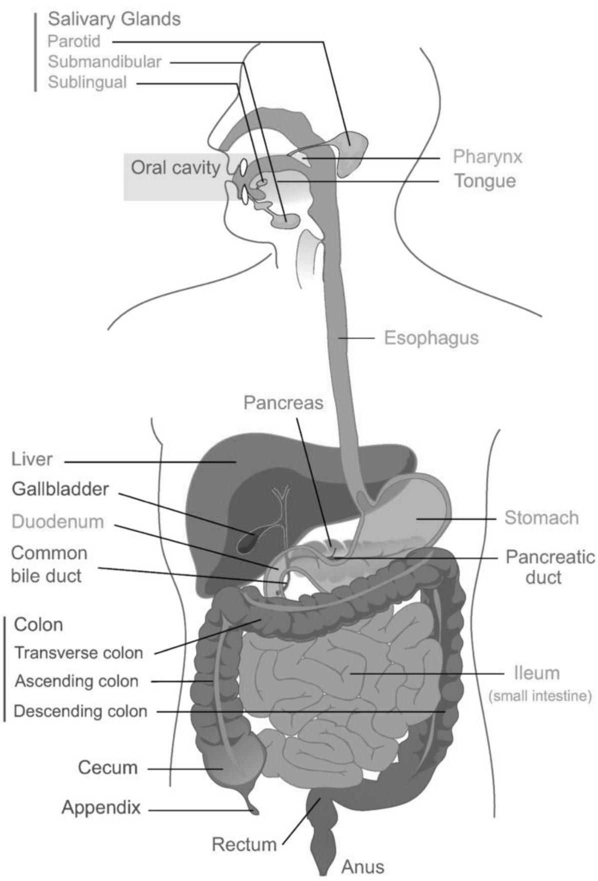

Fig. 2. Composition of the digestive system [6]

The human digestive system comprises organs of the gastrointestinal tract, as well as auxiliary organs: salivary glands, the pancreas, the liver, and the gall bladder.

The whole system can be conditionally subdivided into three segments: [7-8,12]

- The segment for mechanical processing of food;
- The segment for chemical processing of food;
- The segment for removing the unprocessed food and excess food from the organism.

Each segment and each organ of the system perform their unique functions vital for the normal functioning of the whole system.

B. Telehealth marker analysis

According to predictions, the worldwide telehealth market is projected to reach 55.6 billion USD by 2025 from the current 25.4 billion USD in 2020, Fig. 3, with an annual growth of 16.9% within the projection period. The share of Russia in the telehealth market is as little as 3%. However, experts project the growth by as much as 30-50% [1,2,9-10].

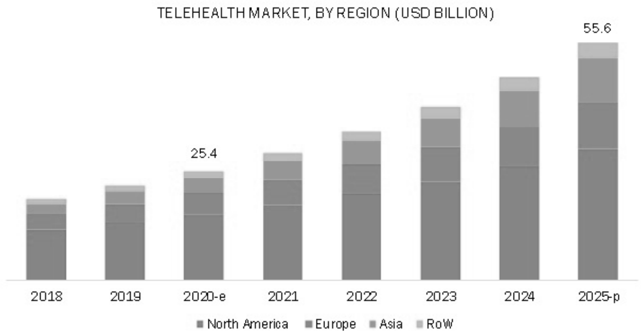

Fig. 3. Worldwide telehealth market (projection to 2025) [9]

The growth of the telehealth market is related to population growth, growing healthcare demand, increased amount of chronic diseases, lack of doctors, progress in information technologies, as well as state support, and increased awareness. However, the market can be negatively influenced by regional regulation differences, fraud, and the use of social networks for health care purposes.

The sudden global coronavirus outbreak is expected to increase the use of telehealth, as these solutions help caregivers communicate effectively with their patients during the pandemic and provide better solutions to their health problems. Thanks to social distancing enforced in various countries around the world, virtual assistance is becoming an increasingly effective solution for safe and better communication. WHO mentioned telehealth as one of the most important services in the COVID-19 response policy [9].

Telehealth can be subdivided into monitoring, consulting, and academic applications. The major players in the global telehealth market are Koninklijke Philips N.V. (Netherlands), Medtronic (Ireland), GE Healthcare (US). Other prominent players in this market include Cerner Corporation (US), Siemens Healthineers (Germany), Cisco Systems, Inc. (US), Teladoc Health Inc. (US), American Well (US), AMC Health (US), MDLive (US), Doctor on Demand (US), Medvivo Group Ltd (UK), Asahi Kasie Corporation (Japan), Iron Bow Technologies (US), Telespecialists Llc (US), GlobalMed (US), MedWeb (US), IMediplus Inc. (China), Vsee (US), Chiron Health (US), Zipnosis (US)[5, 8-10]. The Russian market is headed by applications like SberZdorovie, DOCDOC, Yandex.Zdorovie, Moi Doktor, OnDOC[10]. The system developed is an academic application of telehealth, and it is a logical continuation of the study [13].

C. Analysis of statistics of gastrointestinal tract diseases

The problem associated with diseases of the gastrointestinal tract has become increasingly relevant in recent years since it is inherently linked with food intake and dietary nutrition. The development of this problem, in combination with a high rate of life, provides ample opportunities to create systems and applications to help people with digestive problems [1, 2, 8].

According to studies [11], almost 89% of the world population have pathologies of the gastrointestinal tract. Each 30-year-old person has at least one disease of the digestive system [2, 8]. Fig. 4 shows an example of statistics on gastrointestinal tract diseases in Russia.

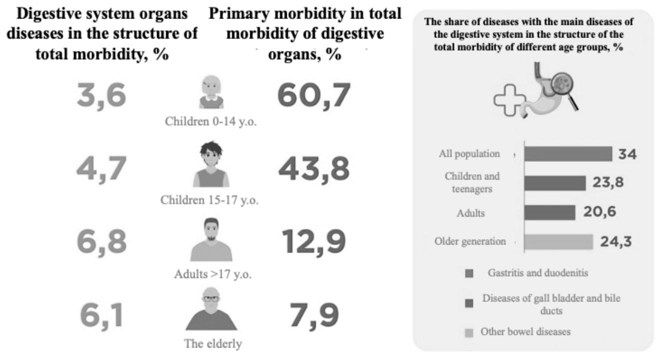

Fig. 4. Statistics of the gastrointestinal tract illnesses in Russia for different age cohorts [11]

Improper nutrition, which has various forms, is the leading cause of problems with the digestive system. It includes overeating and eating heavy food, malnutrition and starvation, irregular meals, hasty snacks, and a poor and unbalanced diet. The digestive tract is negatively affected by poorly purified water and harmful food additives. Also, it is influenced by the poor environment, stress, harmful working conditions, harmful habits, innate predisposition, autoimmune diseases and endocrine system failures, side effects of medications (antibiotics, anti-inflammatory, painkillers, hormonal drugs), violations of sanitary cooking and eating standards that can cause infectious diseases and parasite infection.

III. Methods and Materials

A. Formulation of requirements for the development of an intelligent system

When designing a system with big raw data, the expert system is the most likely choice for implementation. But, like any other, expert systems have a number of disadvantages that do not allow the full implementation of the designed system. One of the common problems is the lack of a large amount of time to attract a specialist in the subject area in the process of filling the knowledge base, classifying data, and then determining the correct result. This problem can be solved by hybrid systems with elements of recommender systems.

To form the requirements for the designed intelligent system, it is necessary to describe the requirements for intelligent and recommender systems in general.

The designed system is related to the class of intelligent systems because it must be capable of accumulating and acquiring new knowledge, conduct human-like reasoning [15]. Fig. 5 shows the classification of intelligent information systems.

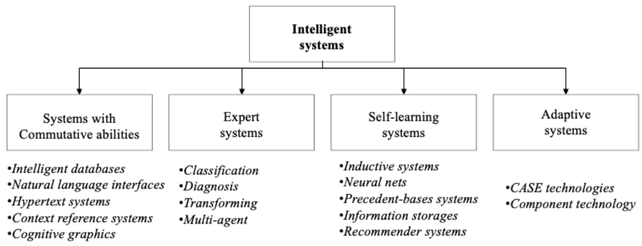

Fig. 5. Classification of intelligent systems

According to the study goal, the system design must combine the working principles of expert and self-learning (recommender) systems. Thus, the developed system of forming the individual meal plan is related to the class of hybrid systems due to combining the features of two aforementioned systems [3].

B. Current knowledge representation models

Currently, three main models (Production, semantic network, and frame knowledge representation) have become the most common.

Production model of the knowledge representation. A production rule is the main part of the production model of representing knowledge. In this model, the facts can be merged into groups using the following rules:

IF <antedecent>, THEN <consequent > [4]

Thus, a production-based system can wield a large number of groups of facts and rules of different levels, causing some difficulties. The difficulties are that there is a need for a strategy for managing the facts and rules and determining the governing metaknowledge [5].

Semantic network. If the system implementation mechanism is complex, then hierarchical semantic networks can be used that include nodes with their own internal structure and allow forming hierarchies of groups of interrelated facts. Constructed networks are easily divided into subnets, i.e., into several levels (spaces). The basis of a semantic network is a directed graph. The vertices of the graph reflect concepts, and the arcs reflect relationships between them.

The special feature of a semantic network is having three kinds of relations:

- Property & value;
- Class & subclass;
- Class element instance [2].

Semantic networks have a significant drawback: data representation is a complex process for extracting knowledge. Most often, this disadvantage occurs when implementing a large network when the graph has to be traversed to extract the required knowledge. Graph traversing may take a lot of time and computing resources [5].

Frame-based model of knowledge representation. In the process of creating a frame model, declarative frames are used, which is a structure that combines a coherent group of statements embedded in the knowledge base at the design stage. In addition to declarative frames, the model can use procedural frames, the main difference of which is determining the value of slots during the operation of the logical inference mechanism.

Slot values in complex expert systems can be numbers, mathematical relations, natural language texts, programs, inference rules, or links to other slots in a given frame or other frames [4].

C. Algorithm of developing expert systems

Any expert system must have four elements: date, knowledge representation mode, database, and the logical inference mechanism.

The data is the original information forming the set of facts and ideas. The difference of this set of factors from the conventional understanding of data is that they are represented in a formal way. Systems capable of self-learning are one of the most difficult to implement.

The knowledge representation model is the model that allows forming knowledge for storage, simple access, and usage.

The knowledge base is a special database having the rules of forming the result and the experience of a person in a specific application area the system is tailored to. It simply stores relations created by the facts between the incoming and result data.

Mechanism of logical inference of data is the mechanism that analyzes and represents new knowledge by comparing data acquired by investigating the application area and rules from the knowledge base

The logical inference mechanism can be formally represented as follows:

$$\langle F, P, R, D \rangle \quad (1)$$

where F is a utility for extracting fact and laws from the knowledge base, P is a utility for checking rules to determine the sequence of relations from the knowledge base to whom rules can be applied, R is a utility determining the sequence of rules in the case when the same facts are the result of a rule, D is a utility performing the action [14-17].

The preparation of an initially broad and extensive knowledge base, as well as the formation of the most appropriate logical inference mechanism, make it possible to use expert systems in working with big data. A properly chosen model of knowledge representation and properly designed system structure can ensure optimal performance on large data sets [15].

To design an expert system, several main stages have to be considered: choosing a subject area, extracting knowledge, choosing design tools, formalizing knowledge in the form of machine procedures, building a knowledge base, developing a semantic interface, developing a logical inference mechanism, developing an explanation method, developing a module for knowledge accumulation and knowledge manipulation [17, 19].

The subject area of the current study is medicine. At this stage, the main causes of pathologies and diseases of the human gastrointestinal tract are considered, the structure of the digestive system is studied, and the main requirements and recommendations for drawing up a diet and proper nutrition for a person with digestive problems are described. Also, in the process of studying the subject area, a classification of the main properties of the digestive system is developed for the formation of an individual nutrition plan, and the main stages of the diagnostic decision-making process are described.

The next stage of the design is knowledge extraction. The aim of this stage is to acquire information required for providing the system with knowledge and determining the levels of elaboration and ways of representing knowledge.

The next stages are choosing the design tools based on decisions on previous stages, the formation of the knowledge base, and the development of the user interface with the scenario of interaction with the system «Expert system – User»

One of the main and most time-consuming stages in the development of a logical inference mechanism since it provides the implementation of a strategy for selecting the appropriate rule or the fact. The logical inference process must have the four main processes [14-19]:

- selecting active facts and rules – forming user preferences, diagnosis, doctor's recommendations, and the system itself;
- comparison – determining possible options for a meal plan based on the facts obtained;
- resolution of conflicts – a selection of optimal components for forming the meal plan;
- execution of the chosen rule – formation of the meal plan itself.

The two final stages - the development of explanation modules and knowledge accumulation-make the system simple and understandable for the user and automate the process of filling and updating the knowledge base.

D. Algorithms of developing recommender systems

Among recommender systems, two main types are the most common [20-22]:

- Content-based filtration;
- Collaborative filtration.

Content-based filtration generates a recommendation based on the user's behavior. In other words, the user is recommended objects that are similar to those that they have already selected earlier [1]. The degree of "similarity" is evaluated based on the features of the objects' content. The disadvantage of this type of recommendation systems is a strong dependence on the subject area and a low degree of increase in the number of recommendations.

Collaborative filtering generates recommendations based on the model of previous user behavior [1]. The model is based either on the single user behavior (similar to content filtering) or takes into account the behavior of several users of the system with similar characteristics. The recommendations often utilize previous choices of a specific user and other users. This approach to recommendations is more effective, but a significant disadvantage is the need to collect a large amount of knowledge before the system starts working properly. To describe the algorithm of the recommendation system, a preliminary formalization of the task of forming an individual meal plan is necessary.

Let there be a set of users of the system ($u \in U$), a set of objects (recipes of the dishes a user may like) ($o \in O$), and a set of events (the actions a user performs on objects) ($\{r_{uo}, u, o, d, rd\} \in D$). Each event is formulated by the user, the object, and the result of this event (r_{uo}) [1, 12]. If necessary, the event should also take into account the user's diagnosis and the doctor's recommendations. The requirements for making a recommendation are the following:

- Predict preference:
$$\widehat{r_{uo}} = Predict\ (u, o, \ldots) \approx r_{uo},$$
- Personal recommendations:
$$u \mapsto (o_1, \ldots, o_k) = Recommend\ K(u, \ldots),$$
- Similar objects:
$$u \mapsto (o_1, \ldots, o_m) = Similar\ M(o).$$

To perform these steps, there are three main algorithms user clustering-based, user-based, and object-based algorithm [20-21].

The first algorithm is based on the principle that similar users (with the same preferences and diagnosis) like similar objects. However, this method does not allow making recommendations for users with an unusual taste preference or a unique diagnosis.

The second algorithm works on a similar principle but taking into account the estimates of previous meal plans for different types of users. However, there is an additional disadvantage with this implementation – new objects added while updating the knowledge base will not be recommended to the user.

The third algorithm uses orientation directly to objects-dishes that can be recommended to the user; that is, the user receives a recommendation based on recipes that received a high rating from him earlier. In addition to the absence of new objects in the recommendations, this algorithm produces the most trivial recipes and practically does not expand the number of dishes.

Thus, these simple algorithms have a number of common disadvantages, such as the inability to generate recommendations for atypical users, the lack of new recommendations when updating the knowledge base, triviality, and the need to store all user ratings in the database.

Singular Value Decomposition (SVD) algorithm can be used to rectify these drawbacks. It is based on the singular decomposition of a matrix; any matrix A with the size $n \times m$ can be decomposed as a product of three matrices: U, Σ, and V^T:

$$A_{n \times m} = U_{n \times n} \times \Sigma_{n \times m} \times V^T{}_{m \times m},$$

where U and V are orthogonal matrices, and Σ is a diagonal non-square matrix [5].

To predict the rating of the dish O for the user U, a vector of the set of parameters for the current user p_u and the vector of parameters for the current dish q_o have to be retrieved. The sought predict is the dot product of these vectors [20]:

$$\widehat{r_{uo}} = \langle p_u, q_o \rangle.$$

In addition to predicting ratings, this method will help to identify hidden features of objects and user interests. However, this method cannot be fully implemented without using machine learning.

Among the properties of recommendations when implementing a recommendation system, one should take into account not only the quality of ranking based on user ratings but also diversity (different types of dishes and recipes), novelty (recommendation of not only the most popular but also new dishes), surprise (constant recommendations of popular recipes may become trivial for the user)

Taking into account the considered algorithms for the development of expert and recommendation systems, functional requirements for the designed system for forming an individual meal plan for individuals with digestive problems were formulated.

E. Generalized algorithm of forming an individual meal plan

The key algorithm of applications in expert systems is the logical inference mechanism, so it will be responsible for creating an individual meal plan for users with gastrointestinal tract diseases.

As mentioned in the previous sections, the inference engine should receive four main elements as input parameters: the user's diagnosis, the doctor's comments, a list of personal taste preferences, and recommendations generated by the system based on the user's data.

Each of the parameters should have its own priority; for example, the user's diagnosis will have more weight in forming the plan than the recommendations generated by the system, but recommendations and personal taste preferences may, in some cases, be prioritized over the doctor's recommendations.

Based on the data obtained, the inference engine should generate a list of active facts and rules that will be used by it when comparing, that is, at the stage of determining the priorities of each rule. In the event of contradictions and disputes (for example, the need for meat products in the diet, provided that the user is a vegetarian), the logical inference mechanism should resolve conflicts taking into account the priorities of each condition. For example, the priority of the condition "vegetarian" will be greater than the doctor's recommendation to consume more meat products, so the system must find analogs of such products that are suitable for people who do not eat meat.

Based on the received list of products and recipes, the logical inference mechanism should form an individual meal plan for the user for the specified period with the distribution of dishes for breakfast, lunch, dinner, as well as a morning snack and afternoon snack (based on five meals a day).

The logical inference mechanism should be controlled using the direct order of the inference mechanism; that is, the conclusion about the formed food plan should be based on the received input data, facts, and rules [7], [8], [15], [23].

In addition to the direct inference sequence, the inference management strategy that allows structuring the inference process and minimize the time to find a solution is required. For the given task, the application can use a strategy of splitting into subtasks, as well as an alpha-beta pruning algorithm. Splitting into subtasks allows selecting several subtasks in the original problem, the result of which is considered as the achievement of intermediate goals on the way to the overall final goal. This strategy is widely used for diagnostic systems, which can include the designed application.

Alpha-beta pruning algorithm allows reducing the search space by removing branches, which are not effective in the process of the search for the optimal solution. This algorithm will minimize the time to identify all the relationships required for the system to work in the knowledge base.

F. Generalized algorithm of forming an individual meal plan

To determine the legal status of the system [24-25] being developed, it is necessary to determine whether it belongs to a number of telemedicine systems that provide medical services or medical care. Article 2 of the Federal Law No. 323-FZ on the Basics of Health Protection of Citizens in the Russian Federation dated 21.11.2011 (further referred to as the Federal Law “Basics of Health Protection”) described the main concepts that can define the considered system as a telehealth application. According to the conceptual framework and description of the definitions of health, medical care, medical service, and telemedicine technologies (for the Russian Federation), the system being developed does not directly relate to the systems covered by this law.

Thus, based on Article 2 of the Federal Law No. 323-FZ on the Basics of Health Protection of Citizens in the Russian Federation, it can be argued that the developed HIS refers to systems aimed at providing medical care to maintain the health of people with diseases of the gastrointestinal tract. However, the system does not provide any medical services since it does not provide medical intervention, treatment of the disease, or rehabilitation of the patient. In addition, the system is not directly a telemedicine technology due to the fact that it does not interact with medical professionals and patients but only performs an auxiliary function to assist in the formation of an individual nutrition plan.

In connection with the above, Article 36.2 of the Federal Law No. 323-FZ on the Basics of Health Protection, which regulates the features of medical care provided using telemedicine technologies, does not impose any restrictions on the functionality of the designed system for the formation of an individual nutrition plan.

IV. Practical Implementation and Results

The initial data for normal operation of the expert system were collected from reference books on gastrointestinal tract diseases, specialized books, and experts with knowledge of the gastrointestinal tract diseases.

The generalized algorithm of the system can be represented as follows [2]:

1) The user identifies the disease symptoms. Usually, these symptoms are subjective as they are based on the description of the user’s feeling.

2) The user inputs symptoms as input data.

3) The system interprets the symptoms as the initial data.

4) The logical inference mechanism using the pre-defined production rules is launched.

5) A recommendation is formed; the recommendation may have a list of products having different usefulness probability.

Fig. 6 shows the structure of the system.

Unlike many other pathological processes in the body, the way of nutrition in diseases of the digestive tract is an important element of treatment, which determines its effectiveness, the speed of restoring the normal functioning of the stomach, and eliminating the symptomatic picture [21-25].

There are many different stomach diseases: pancreatitis, cholecystitis, polyps, ulcers, gastritis, stomach infections. Also, the stomach may have different acidity, which directly affects the nutrition process. Therefore, depending on the diagnosis, it is the physician that prescribes the necessary diet [15-17], [21], [23].

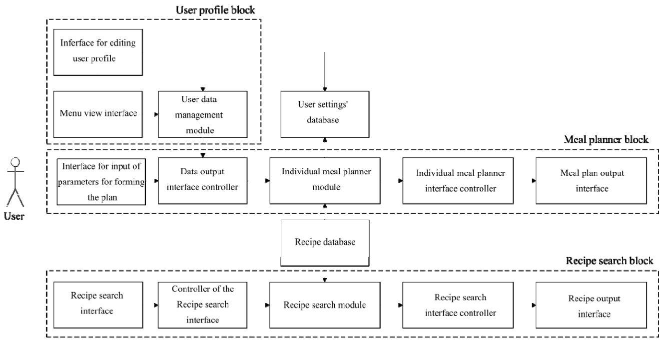

Fig. 6. Block diagram of the HIS for helping people with gastrointestinal tract diseases

All therapeutic diets used for diseases of the gastrointestinal tract combine some general principles:

- split meal regime, 6-8 meals during the day.
- cooking. In the mild dish, the products are crushed or ground. Diet for the stomach, liver, pancreas, and bowel must not have coarse and hard particles that will mechanically disturb gastric and intestine mucosa, possibly causing a relapse of the disease.
- sour and spicy dishes, juices, kompots, picklings, smoked products, fat meat, and fish are to be removed. Fried dishes are to be excluded.
- the temperature of foods and drinks should be monitored.
- food safety should be taken care of. One should consume fresh products and freshly cooked dishes and avoid semi-finished food products and food with preservatives.
- for recovery, it is necessary to have a sufficient amount of easily digestible protein in the diet.

In the process of investigation [23], the main properties of the digestive were classified, as shown in Fig. 7.

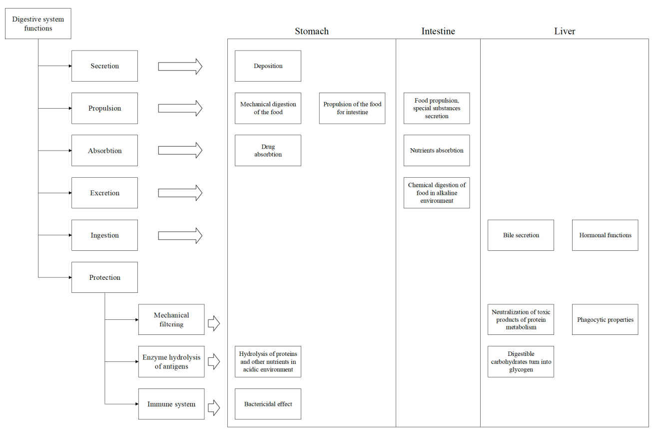

Fig. 7. Classification of the main properties of the digestive system

This classification was used for forming an individual meal plan for a user.

The system assumes one type of user. It is a person wanting to form an individual meal plan taking into account the person's disease and personal taste preferences.

Table I shows a typical scenario of forming an individual meal plan.

TABLE I. A TYPICAL SCENARIO FOR FORMING AN INDIVIDUAL MEAL PLAN

User action	*System response*
1. The user authorizes in the system using the credentials	2. The system locates the user in the user database 3. The system authorizes the user and transfers the user to the main app window
4. The user inputs the diagnosis and the doctor recommendations in the respective fields and presses the button to go to the next step	5. The system memorizes the user input and transfers the user to the second stage to input personal taste preferences
6. The user inputs culinary preferences like favorite dishes, products, and possible nutrition restrictions and presses the button to go to the next step	7. The system memorizes the data input by the user 8. The system launches the algorithm for making recommendations 9. The system outputs recommendations obtained by processing user data
10. The user chooses the fitting dishes and products from recommendations and presses the button to go to the next step	11. The system memorizes the data chosen by the user and outputs the field for selecting the end date for forming the meal plan
12. The user inputs the end date and presses the button to form the meal plan	13. The system launches the logical inference mechanism that forms the individual meal plan for the user 14. The system outputs the obtained meal plan with the set end date
15. The user looks through the formed plan and saves it in the section for personal meal plans	16. The system saves the formed plan in the required section

An alternative scenario of forming an individual meal plan is shown in Tables 2-5.

TABLE II. ALTERNATIVE SCENARIO OF AUTHORIZATION

User actions	*System response*
1. The user authorizes in the system with the user credentials	2. The system does find the current user in the user database 3. The system displays the message that the user is not found and offers registration
4. The user goes to the registration page and registers	5. The system writes user data in the database and goes to the next step
6. The user authorizes in the system	*The system does to step 3 of the typical use scenario*

TABLE III. ALTERNATIVE SCENARIO – EDITING OF MEAL PLAN

User actions	*System response*
4. User goes to the section with individual meal plans	5. Systems shows the user all user meal plans
6. User chooses the plans and presses the "edit" button	7. System goes to the mode of editing the meal plan
8. User changes input parameters	*The system goes to step 7 of the typical scenario*

Fig. 8 shows a generalized use case diagram for forming the individual meal plan by the user [6].

TABLE IV. ALTERNATIVE SCENARIO – EDITING OF MEAL PLAN

User actions	*System response*
15. The user looks through the formed plan and rejects it if there are contradictions	16. The system displays the message that the plan can be re-formulated 17. The system transfers the user to the first stage of forming a meal plan *(see step 3 of the typical scenarios)*

TABLE V. ALTERNATIVE SCENARIO – RETURN THE PREVIOUS STEP

Use actions	*System response*
6-12. At any step of forming the meal plan, the user can press the "return" button and edit the data entered earlier	5-12. The system should return the user to the previous stage to edit the input parameters
4-12. The user changed in previous input data	5-12. The system removes old data, memorizes new data, and goes to the next stage.

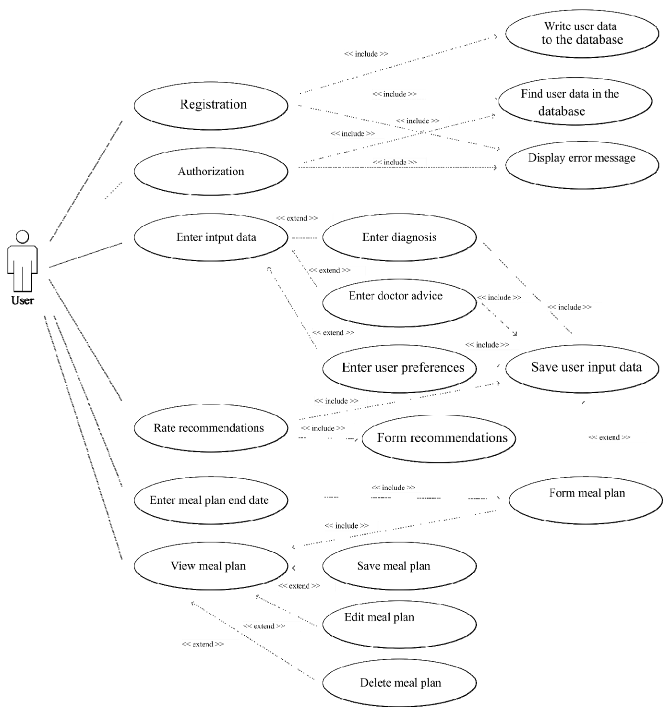

Fig. 8. Generalized use case diagram for the system

Once the algorithms are developed, the properties of the digestive system are classified; the structure of the HIS for helping people with gastrointestinal tract diseases was formed, as shown in the diagram in Fig. 8.

To implement the system, it is necessary to have a universal platform that would allow you to always have access to the information provided and the meal plan. Therefore, the most reasonable solution is to use an Android smartphone (the most common operating system) as a platform for the designed system. The app should also be provided with the database of knowledge, facts, and rules that will form the final individual meal plan. This requirement can be implemented when creating an expert system. The system user interface forms are shown in Fig. 9-14.

V. Conclusion

As a result of analyzing methods and technologies of the design of intelligent systems, the preferable methods of developing a hybrid intelligent system for forming individual meal plans were identified. The conducted analysis allowed making corrections in the functional requirements to the considered recommender system, as well as potentially improve its performance and utility due to the most productive methods.

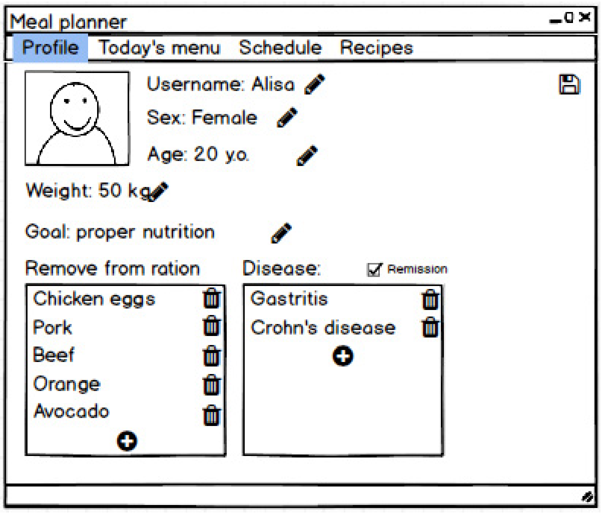

Fig. 9. Hybrid Intelligent System UI Prototypes (Personal Information)

UI Prototypes was created in Balsamiq Mockups 3.

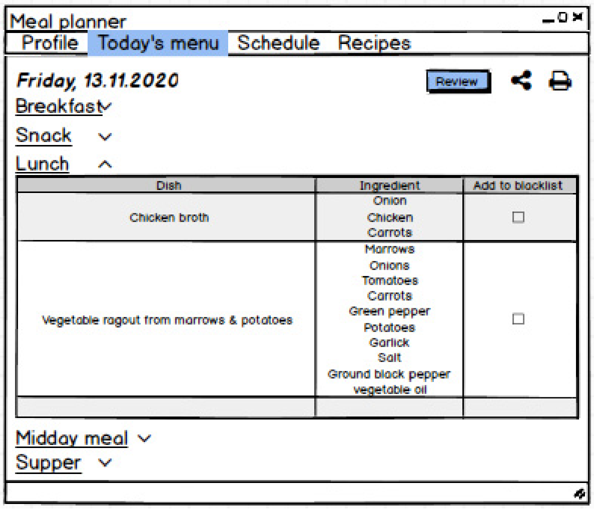

Fig. 10. Hybrid Intelligent System UI Prototypes (Menu)

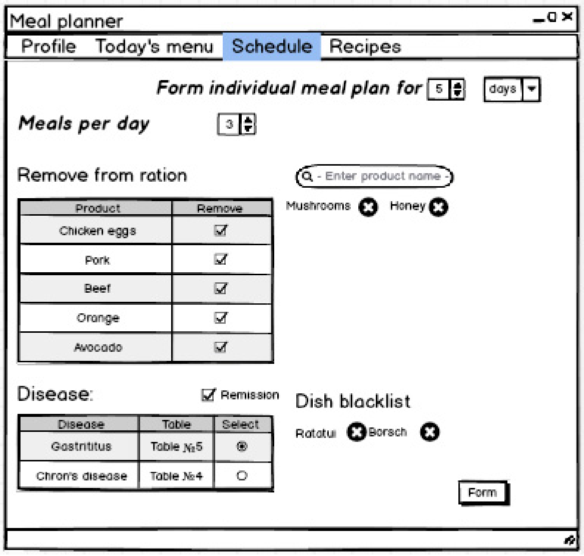

Fig. 11. Hybrid Intelligent System UI Prototypes (Schedule for 6 days)

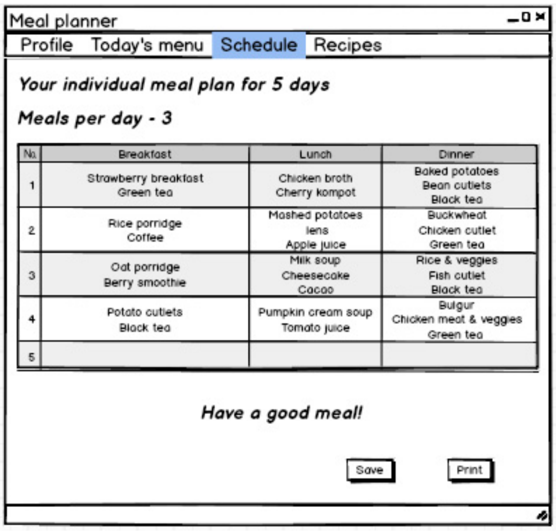

Fig. 12. Hybrid Intelligent System UI Prototypes (Schedule for 6 days)

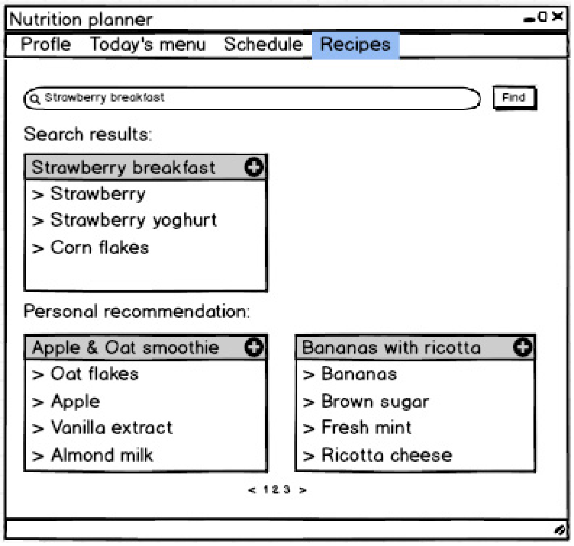

Fig. 13. Hybrid Intelligent System UI Prototypes (Search)

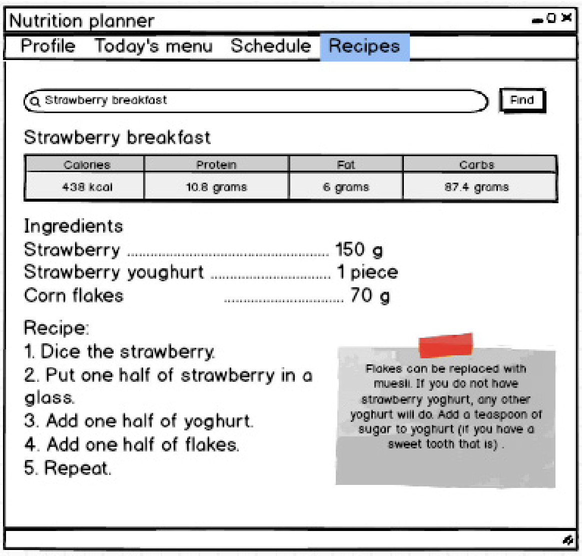

Fig. 14. Hybrid Intelligent System UI Prototypes (Recommendation)

Based on the process of describing requirements to the system, we chose the SVD algorithm as the optimal algorithm for forming recommendations with collaborative filtration; the input data for the logical inference and its main stages are defined. Besides, we identified the need to accumulate knowledge and use experience in subsequent queries of other users because the system can potentially work with Big Data.

Once the functional requirements and design methods were chosen, the analysis of legal regulation of the mobile applications' market was conducted. The analysis showed that the system could be developed without violating Russian regulations.

Besides, the paper considered a generalized algorithm of forming an individual meal plan and presented a generalized use scenario for the expert system with a description of one variable user actions and the corresponding system response, as well as the use case diagram.

As a result of analyzing the algorithms of designing intelligent systems, we determined the stage-wise process of creating the hybrid intelligent system for forming individual meal plans. Formulation of requirements to the system and description of the generalized system algorithms allowed finishing the first stage of the development of the considered expert system.

For further development of the system, the next points should be considered:

- For a more proper formulation of the plan displayed to the user, previously accumulated knowledge and experience should be used for further planning of meals. For better meal planning, there should be a possibility to edit the plans in the cases when a recommended product or dish is not fit for the individual user meal plan.
- The application should have the capability to work with Big Data because the system is faced with the task of forming individual meal plans based on the previously formed knowledge about previous meals, user preferences, previous experience, and doctor's recommendations. As all this implies a lot of conditions, symptoms, and different food ingredients, dishes, and products, the capability of working with Big Data is one of the major requirements the system has to meet.

We concluded that the considered application could not be classified as a system directly selling and providing medical services. It is a part of the system for self-diagnosis and first aid because the application is aimed at forming individual meal plans, including those for individuals with diseases of the gastrointestinal tract. However, nutrition, including healthy nutrition, is currently not defined as a medical service.

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