

Creation of Exercise Plan Using Rule-based System

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Abstract — Nowadays, the modern world strives to live life healthier. With the influence of the virus *COVID-19* on everyday life, it is difficult to maintain motivation and training routine. By using technology, overcoming those difficulties can be easier. This paper presents the implementation of the system for helping users during exercise, filling the role of a digital personal trainer. The system mimics the reasoning of a human expert in proposing a suitable exercise plan based on the current user's condition. Also, the system supports the process of monitoring the current user's status during exercise, acts on changes, and shows certain messages concerning the displayed status. The system uses rules to determine which exercises are most suitable for a particular user, as well as the messages that will be shown during the exercise. The system is implemented using a system based on rules.

Keywords — Rule-based systems, creating of exercise plan, representation of domain knowledge, Drools

I. INTRODUCTION

Regular physical activity contributes to the better health of each individual and reduces the risk of disease. The lifestyle of many individuals includes spending more time sitting in offices, cars, cafes, with little time left for activities such as walking or exercise. Staying indoors at home is even more present now with the appearance of the *COVID-19* virus [1].

The lack of physical activity contributes to the worsening of health [2][3]. It is estimated that physical inactivity worldwide is the primary cause of approximately 21-25% of cases of breast and colon cancer, 27% of cases of diabetes, and approximately 30% of cases of ischemic heart disease [2]. The older people get, the less they engage in physical activities, although then exercise is more necessary. The World Health Organization (WHO) claims that the number of obese people has tripled since 1975, and in 2016, more than 1.9 billion adults over the age of 18 were overweight. Of those 1.9 billion, over 650 million were obese, representing 13% of the world's population [3].

Even if people decide to dedicate themselves and have a desire to increase physical activity through exercise, they face the problem of incompetence, they do not have enough knowledge to do the exercises properly, as well as to determine or create the exercise program that is suited for them. Paying for a personal trainer is expensive and not everyone can afford it, and the problem in watching some videos e.g. Youtube videos with the exercise program is that it is not sufficiently adapted to the individual that is watching it. The system we propose would be especially useful in situations where people do not have access to gyms as well as personal trainers. One example is the current situation, with the Coronavirus

pandemic, especially in the spring of 2020, which has led to limited contacts and the limited use of shared gyms.

The goal of the research was to develop a system that proposes a specific exercise plan to the user which is based on his current physical condition. The motives are to adapt the exercise plan to the specific user, avoid the cost of paying a personal trainer, and save time that the user would spend finding an adequate exercise program.

In many situations, the knowledge and time of experts are expensive and not available to everyone. Expert systems are intelligent computer programs that use inference mechanisms and a knowledge base in which the knowledge of experts is stored [4]. Conventional programs use data and problem-solving algorithms, while expert systems use declarative written rules and reasoning and separate program code and knowledge. The first expert systems appeared in the early sixties of the twentieth century, and today they are applied in the fields of diagnostics, design, planning, repair, learning, etc.

The topic of the paper is a system based on rules that proposes the user an adequate exercise plan following his current physical capabilities and monitors his progress (exercise history), based on which the exercise plan is improved. The system also allows its users to monitor their health statistics during exercise.

This paper aims to help users who do not have domain knowledge and resources for individual training to have a quality exercise plan adapted to the current physical condition of the user.

The system was developed as a web application, with the idea of making it available to potential application users. To access the application, users only need a web browser that has Internet access. Domain knowledge of creating an adequate exercise plan and monitoring health status during exercise was realized by specifying rules in the Drools^a tool and using the MySQL database.

We organize this paper in the following manner. In Section II, we present the related work. In Section III, we show the analysis of similar solutions. In Section IV we discuss system design. In Section V, we show how Drools can be integrated into the system architecture and some parts of system implementation. In the last section, we conclude this research, indicate some of the limitations, and future work.

II. RESEARCH QUESTIONS AND METHODOLOGY

The research in this paper will try to give answer to 2 questions:

- Is it possible to make a personal workout system that uses personal user data to generate a suitable exercise plan?

^a <https://www.drools.org/>

- If so, can the creation of an exercise plan be done by using a rule-based system where domain knowledge is stored in the form of some formally defined rules?

Methodology consists of following:

- Review of related work concerning the expert systems that are designed to solve problems mimicking the human experts. There are many references how formally defined rules have been used to represent expert knowledge.
- Analysis of some of the existing popular applications that are used for making exercise plans
- Collection the expertise from the field of exercise that will include consultation with field experts and consulting books in the field of sports medicine.
- Choosing an appropriate rule-based systems

III. RELATED WORK

Knowledge-based systems can be a key solution for automating some processes. These systems simulate human reasoning in a specific domain. One type of knowledge-based systems is the expert systems. They are designed to solve problems using the knowledge of an expert [5].

Compared to conventional programs that solve the problem by executing a well-defined algorithm, expert systems rely on a knowledge base in which they find claims from the domain of the problem, usually written in the form of *if-then* rules and facts about the problem itself [6].

Expert systems are computer systems that mimic human experts. Domain-specific knowledge is stored in a knowledge base, which expert systems use to infer and derive new knowledge [7]. The expert system consists of a Knowledge Base, an Inference Engine, and a User Interface. The inference module contains an agenda in which satisfied rules are placed waiting to be executed. As it is not possible to activate several rules at once, it is necessary to choose a strategy for determining the rules to be executed [8]. The resonator has two modes of operation: forward chaining and backward chaining.

An example of using Drools as a business rule management system to create an expert system can be seen in [9]. In that paper, authors have created a system to support the work of wineries, where formally defined rules have been used to represent expert knowledge. The paper shows how expertise in the field of enology can be presented in the form of Drools rules.

[10] describes research that states that expert knowledge of calculating insurance policies manifests itself in the form of Drools rules. It describes the convenience of updating the rules if some changes occur, so new rules should be added to the system as soon as possible. These changes must be made on time, which is achieved by using rule-based systems.

In [11], the authors describe a system for recommending courses to students using the rule-based system. The authors state that the reasoning process uses information on student achievement in previous courses, application requirements for certain courses (in terms of courses that the student must have previously taken), and

results from a personality test based on Holland J. L.'s theory of career choice.

Paper [12] describes a rule-based system that helps farm management by monitoring events that occur in real-time. The system based on certain parameters such as rate irrigation and selected parameters from field and weather conditions determines the most suitable ways to treat crops.

Another system that resonates with the use of rules is described in the paper [13]. The rules are written to help tourists determine the places of visit at a particular location, based on the user's personal preferences and interests. Events that tourists should attend are also recommended.

In [14], authors argue that the motivation for creating a rule-based system comes from benefits that are achieved when domain knowledge is written in the form of rules (declarative programming) compared to conventional programming code. Knowledge represented in the form of rules is easier to read, maintain, and change, even for those unfamiliar with programming. Also, such a representation of knowledge can be easily exchanged and used in other knowledge-based systems.

IV. ANALYSIS OF EXISTING SOLUTIONS

Before the implementation of the solution that is proposed by the authors, an analysis of two popular applications was done. The analyzed applications are PEAR - Personal Fitness Coach [15] and Workout Trainer: home fitness coach [16]. The analysis and the conclusions are presented in the rest of this section. The conclusions are used to determine the basic requirements and desirable features for the proposed solution.

A. PEAR - Personal Fitness Coach

PEAR - Personal Fitness Coach is a mobile exercise app. When a user opens the application for the first time, it is necessary to provide the application with pieces of information like users' gender, height, weight, and date of birth.

On the homepage of the application, the user can choose some of the available activity-based exercises. Those exercises can be filtered based on their type (e.g. running, cycling, walking, etc) and their duration. Every exercise that is suggested for the user, comes with the name of the trainer who has supplied it and with instructions for executing the exercise. Besides the textual description of the exercise, additional materials like video or audio recordings can be also found.

There is a possibility to search for exercises based on activity, location, duration, and user level. It is possible to search for training plans based on the effect that the user wants to achieve, e.g. weight loss, a race at 5 thousand meters, etc.

Monitoring the heart rate during training is possible if the user connects the application to the appropriate device. This data is stored and thus the progress of the user is recorded.

The application supports two types of users, regular or PEAR+ member. PEAR+ membership is paid. PEAR+ members have access to more advanced application functionality like assigning fitness profiles, regulation of the balance of intensity, and level of activity, as well as the use of other functionalities.

B. Workout Trainer: home fitness coach

Workout Trainer: home fitness coach is also a mobile exercise app, which is more popular than the previous one because it has a higher number of downloads, as well as a higher rating in the Android store. When entering the application for the first time, it is necessary to answer questions about the user's activity, the goals he wants to achieve, the types of training he is interested in, as well as to enter data on gender, date of birth, and weight.

Exercises that are suggested on the homepage of the application, can be filtered by exercise goals, muscle groups, etc. Users can access the information of the particular trainer and see all exercises they have published. Users have the options to choose an exercise program and to follow it.

Unlike the previous analyzed application where exercises are searched by certain characteristics, in this one, the search is enabled only by their name.

In the application, there is an option for users to become paying PRO+ members. Those members get more opportunities in using the application, such as reviewing all possible exercises and training plans, monitoring user heart rate during training, etc.

C. Summary

The good features of the analyzed applications are that they have detailed descriptions of exercises accompanied by appropriate audio, video, or images, the ability to monitor user heart rate during training, the storing of user history containing the records like the time user spent exercising or what mileage has user achieved in exercise. All the mentioned functionalities have been adopted as crucial and will be implemented in the system described in the paper.

It has been noticed that certain applications allow the user to independently choose a training program, which as a consequence can lead to a negative counter effect. There is a risk of deteriorating health because the user is not skilled enough to determine an exercise plan. The idea of the user choosing a training program that is not proposed by the application was not adopted. Also, the analysis of applications showed that almost all available training programs consist only of one example of muscle/body part exercise, where there is no adequate warm-up exercise before the conditioning part or the main part of the training, and that there are no stretching exercises that are suitable after the executed main part of the training. Also, a field expert that is consulted stated the necessity of warm-up and stretching exercises. The system proposed in the paper will address the previous observation in such a manner that it will provide the users with more than one example of muscle/body part exercise in chosen training, that will always have an adequate combination of warm-up and stretching exercises.

Monitoring of heart rate in the analyzed applications is reduced to only recording the value of heart rate during training, where users can only view the statistical data. There is no reaction of the system if the user's heart rate has become irregular.

V. SYSTEM DESIGN

Before the design of the proposed application, it was necessary to collect the expertise from the field of exercise that will be integrated into the system. That knowledge

was collected from adequate books (books of the American College of Sports Medicine [17] [18] and Anatomy of Strength Training [19]) and in consultation with a field expert.

The exercise assistance system is designed as a web application that allows each user to search for exercises based on their characteristics, where each exercise contains detailed information about its execution. The application allows the user to choose the exercises following his current physical abilities, to monitor user progress, and to improve the user exercise plan in accordance to achieved user progress and shifted personal boundaries. Heart rate monitoring in the application is raised to a whole higher level. Besides information about heart rate during exercise, the system actively reacts to any irregularities in heart rate. System supports defining limits, for lower and upper optimal heart rate. During exercise, the system will alarm the user if his heart rate is outside the defined limits of the desired intensity, and will advise the user to take certain actions to avoid deterioration of his health.

The system supports two types of users, the administrator and the regular user (person who wants to exercise). The administrator oversees entering new and modifying existing exercises. Its role is to enter the correct data about each exercise, to assign/choose the exercise type, intensity, or group of muscles to which the exercise belongs. Also, the administrator is responsible to supply exercise steps/descriptions, and to upload exercise pictures and/or videos.

The regular user upon his first usage of the system must enter data on his/her physical condition, as well as to fill in an international questionnaire on physical activity [18]. After that, the user can choose an exercise plan based on his current physical abilities. The system requires that the user update his current physical condition every four weeks. An option available to the regular user is to monitor the heart rate during exercise. Clearly defined limits of the upper and lower optimal heart rate for exercise are set depending on the intensity assigned to the user, if there are certain deviations from these limits, a message is displayed on the screen. This functionality is intended to work only by connecting the system to an adequate device that can measure heart rate.

Ten classes (*Alarm*, *Exercise*, *HearthBeatTracking*, *MusclesGroupDate*, *Picture*, *QuestionnairePA*, *User*, *UserHealth*, *UserPlanner*, *VerificationToken*) and seven enumerations (*ACTIVITY_LEVEL*, *BLOOD_PRESSURE_CLASSIFICATION*, *EXERCISE_TYPE*, *INTENSITY*, *MUSCLES_GROUP*, *NUTRITION_LEVEL*, *USER_ROLE*) make up the application data model of the system. The classes and enumeration used for description of part of model which is used to determine the user exercise plan are shown in Figure 1.

VI. SYSTEM IMPLEMENTATION

The system implementation is made up of the client-side, the server-side, the rule-based system, the database, and the image and video storage database (Figure 2). The client-side was developed using Angular, for the server-side Spring was used using the REST service, and the knowledge-based system was implemented using Drools. The data is stored in a MySQL database, except for images and videos for which Firebase was used.

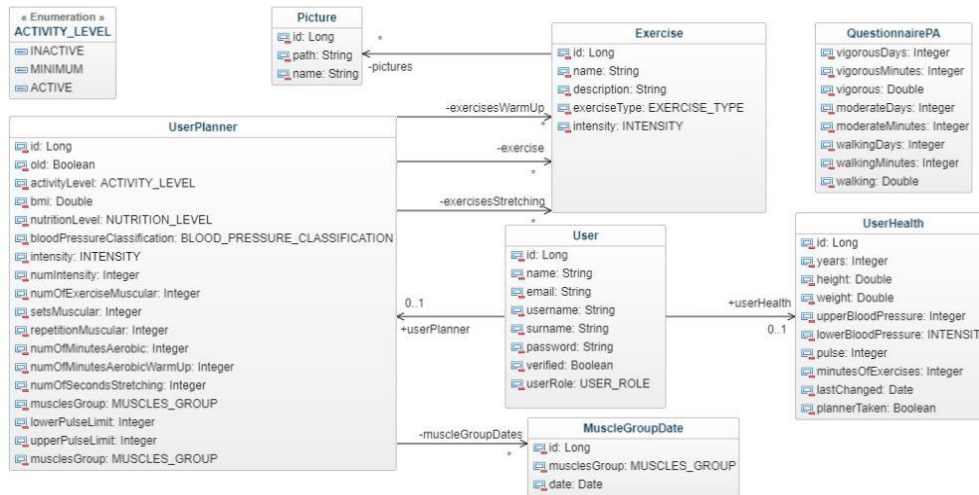


Figure 1. Class diagram for exercise plan

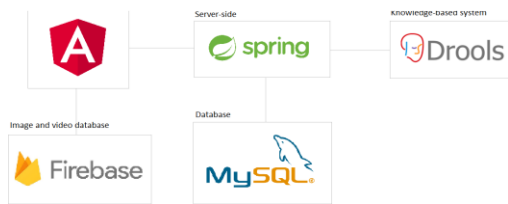


Figure 2. System architecture

As mentioned earlier, the system is intended to recommend an exercise plan to the user, as well as to monitor his current physical condition during exercise. Therefore, the main functionalities of the system are:

- Determining the exercise plan for the user
- Monitoring the heart rate during exercise and writing the appropriate messages based on that
- Searching for exercises.

Monitoring of the user's condition during exercise is implemented as a simulation in the current version of the system. The implementation of knowledge-based systems will be described in more detail below.

The system described in the paper is realized as a rule-based system, where the knowledge base contains a set of rules that represent the domain knowledge of the expert. Knowledge in systems based on rules is presented in the form of production rules, in IF-THEN form. The assumptions that must be met are written in the section after the IF (the left side of the rules), and if at least one of the assumptions is not met, the action/s will not be performed. Actions are written after the THEN keyword, the right side of the rules represents the conclusion that the expert would come to based on the factual situation. Logical operators are supported over assumptions, usually, these are: and, or, not and parentheses.

The knowledge base contains a set of rules, while a set of facts or things that are known are in working memory. In the inference module, conclusions are drawn based on the current state of the working memory and a set of rules. Conclusions can add new facts or modify or delete existing facts in working memory that can cause some now rules to be executed or can lead to the cessation of compliance with certain rules.

Drools has been chosen in the implementation of the rule-based system because it is written in Java language as

the rest of the system and because of authors positive previous experience with Drools. The rules that are written are divided according to the functionality it supports - determining the exercise plan, monitoring the pulse during exercise, or searching for exercises.

A. Determining the exercise plan

Determining the exercise plan is divided into two groups. The first group consists of rules relating to the determination of user characteristics that can be concluded based on data on current condition and the international questionnaire on physical activity if data on the condition of users are entered for the first time, otherwise, the time spent practicing is considered. There is no need to determine these characteristics every time the user requests for an exercise plan because they will always give the same results, as long as they are not changed, the data on the physical condition of the user is updated. The second group of rules includes rules that are invoked during each exercise plan request and that determine the exercise plan based on user characteristics that are determined from the first set of rules and others that are updated with each exercise plan request. All rules are based on the knowledge of experts, the books of the American College of Sports Medicine, and the knowledge of experts were used.

Based on the completed questionnaire, it is determined how physically active the user was in the previous seven days. The questionnaire is used to determine the level of physical activity only if the user accesses the system for the first time. Otherwise, it is determined based on the hours spent practicing. Listing 1 shows one of the rules for determining activity levels.

```
rule "Activity level active 1"
  agenda-group "planner"
  salience 20
  when
    QuestionnairePA(vigorousDays >= 3,
vigorous >= 1500)
    $p: UserPlanner(activityLevel ==
null)
  then
    modify($p){setActivityLevel(ACTIVITY_LEVEL.AC
TIVE);}
end
```

Listing 1 Example of rules for determining activity levels

The variable vigorous represents the metabolic equivalent (MET) in minutes weekly [18]. It is calculated by multiplying the MET level for the type of activity, in this case, high-intensity activities evaluated by 8 METs, multiplied by the duration of the activity expressed in minutes during the day and by the number of days per week when this form of physical activity is performed [18], which is found out from the questionnaire. In addition to activity levels, the first group of rules determines the level of nutrition, classification based on blood pressure, whether the user is older than 64 years, exercise intensity, number of seconds of stretching exercise, number of sets performed (refers to strength exercises), and the upper and lower pulse limits during exercise.

Determining the level of nutrition depends on the BMI (Body Mass Index). BMI represents the relationship between body weight and body height. It is calculated by dividing the weight in kilograms by the squared value of the height in meters [18].

The classification by blood pressure determines the possibility that the user has hypertension, the existing phases are "normal", "prehypertension", "first stage hypertension" and "second stage hypertension". Classification is based on upper and lower blood pressure.

The intensity assigned to the user depends on several previously assigned categories, namely: activity level, whether the user is older than 64 years, and classification based on blood pressure. Records are kept of how many times an exercise plan with a certain intensity has been requested.

Determining the upper and lower heart rate limits during exercise depends on the resting heart rate, age, and intensity assigned to the user. The maximum heart rate during exercise is calculated according to the formula:

$$207 - (0.7 * \text{age of the user}).$$

It is then necessary to calculate the difference between the maximum heart rate and the resting heart rate, which is the HRR (Heart Rate Reserve). Each intensity has its range:

- Low 30% - 40%
- Moderate 40% -60%
- High 60% -90%

The lower and upper pulse limits are calculated by the formula:

$$(\text{desired intensity} * \text{HRR}) + \text{resting pulse}.$$

The difference between the lower and upper limits is that the value of the desired intensity at the lower limit will represent the lowest percentage from the intensity range, while the upper limit will represent the highest percentage from the range [17]. The rule for determining the upper and lower pulse limits, which is activated if the user is assigned a high intensity, is shown in Listing 2.

In the second group of rules, in addition to exercises, the minutes for cardio (aerobic) exercises, the number of exercises, and the number of repetitions for strength exercises are determined. What influences the determination of these parameters is the activity, the number of times the exercise plan is requested with the currently assigned intensity (each time this group of rules is started, this value increases by one), age. Also, the level

of nutrition and the classification of blood pressure are affected. These characteristics are taken into account only after the time and number of exercises are assigned. One example of their use is that if the user is malnourished and has no hypertension, he will be given more strength exercises, and the duration of cardio exercises will be reduced.

The choice of exercises that are added to the list of main exercises and stretching exercises is also influenced by the selected muscle group. When selecting a muscle group, the one that has not been exercised for the longest time is chosen, and if there is a muscle group that has never been exercised, it will be selected.

The list of exercises for warming up or relaxing muscles includes one cardio exercise that is weaker than the currently assigned intensity, or is equal if the assigned intensity has a value of "low". The main exercise includes one cardio exercise and strength exercises. The list of stretching exercises contains one stretching exercise from each muscle group and all stretching exercises that are in working memory, and belong to the currently exercised muscle group.

B. Monitoring the condition of users during exercises

Pulse monitoring during exercise was achieved using

```
rule "Calculate limits, intensity vigorous"
  agenda-group "planner"
  salience -1
  when
    UserHealth($pulse: pulse, $hrr: (207
- (0.7 * years) - pulse))
    $p: UserPlanner(intensity ==
INTENSITY.VIGOROUS)
  then
    modify($p){
      setLowerPulseLimit((int) (0.6 *
$hrr + $pulse)),
      setUpperPulseLimit((int) (0.9 *
$hrr + $pulse));
    }
  end
```

Listing 2 Determination of upper and lower pulse limits

```
rule "Breathe deeply, no hypertension"
  salience 10
  when
    $hb1: HeartBeatTracking( $userId:
userId, $tp: (upperPulseLimit + 0.05 *
upperPulseLimit), $tp < currentPulse,
(bloodPressureClassification !=
BLOOD_PRESSURE_CLASSIFICATION.HYPERTENSION1
&&
    bloodPressureClassification !=
BLOOD_PRESSURE_CLASSIFICATION.HYPERTENSION2
))
    $n: Number(intValue == 0) from
accumulate(
  $hb2 : HeartBeatTracking(
    this != $hb1,
    userId == $userId,
    $tp >= currentPulse,
    this before[0m, 10m] $hb1),
    count($hb2)
  )
  not (Alarm(userId == $userId))
  then
    insert(new Alarm($userId, "Breathe
deeply"));
    delete($hb1);
  end
```

Listing 3 Example of triggering an alarm

Complex Event Processing (CEP). The events that are processed are the current pulse of the user during the exercise. Events to which attention is drawn, i.e. the alarm is triggered, are deviations from the defined upper and lower limits of the assigned pulse. Depending on the user's health characteristics, whether it is below the lower or above the upper defined limit, an appropriate message is sent to the user. Listing 3 shows one of the possible alarm triggering cases. The conditions that must be met are: deviation from the upper limit of the pulse is greater by 5%, no hypertension, and deviation lasts more than 10 minutes.

C. Search exercises

The exercise search was accomplished using global variables and queries. Before starting the rules, it is necessary to set the values of global variables. They represent the parameters by which the exercises are searched. Also, it is necessary to insert all the exercises from the system into the working memory. The result of the reasoning is placed in the global variable exercises which is initially an empty list.

The application described in this paper is a free and open-source project. Everyone is welcome to contribute code^b, documentation, tests, bug reports, etc. For easier understanding of some of the application functionality, we also give a short video demonstration^c of application usage.

VII. CONCLUSION

The paper presents how a personalized system was developed to help the user in exercising using expert knowledge presented in the form of production rules. The knowledge used was collected from the books of the American College of Sports Medicine and in consultation with an expert. The advantages and disadvantages of the existing solutions are analyzed and compared with the implemented system. The specification and implementation of the system, which consists of three applications, is presented. The rule-based system contains the knowledge of experts. The system was developed using the Drools tool.

The current version of the system does not allow the user to connect to an actual device for monitoring heart rate during exercise, but a simulation was done to present how monitoring of the user's condition during exercise could be accomplished. In addition to the mentioned functionality, the system could be improved with an option for the administrator that would allow him to add new rules based on certain templates.

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^b source code - <https://github.com/MicaTravica/trinsi>

^c demonstration of usage - <https://github.com/MicaTravica/trinsi/raw/master/video.mp4>