An Expert System Framework for Lifestyle Counselling

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Abstract— **The implementation and support of proper lifestyle is a key factor in preventing chronic diseases and also in the management of already manifested ones. This paper presents a CLIPS (C Language Integrated Production System) based framework that can be used to develop expert systems for assisting users to learn a proper lifestyle. The relevance and applicability of this system is shown in the domains of diet and exercise based lifestyle management and workplace related ergonomics. Preliminary results show that the framework can properly evaluate the formulated basic knowledge bases and is suitable for the tasks intended.**

Keywords – CLIPS; expert system; lifestyle assessment; telemedicine; work ergonomics.

I. INTRODUCTION

Lifestyle is a key factor in the prevention and management of chronic diseases [1]. A shortage of manpower in professions aiding people to "live a healthy life" (e.g., doctors, dietitians, ergonomists, etc.) have surfaced recently, and is growing gradually, as the number of treatments to be done is increasing faster than that of such experts [2]. A Lifestyle Coach Framework, aimed at improving people's way of living, was developed for creating expert systems that could be used in solving these problems. With this framework, targeting general audiences is possible, just as well as focusing on specific patient groups, like diabetics. Two areas, logging-based diet and exercise oriented assessment, and workplace ergonomics were investigated. Their common ground is that for both, evaluation of user behavior can be achieved by analyzing events with expert systems (which differ only in the knowledge used).

Expert systems (ES) have been used in many application areas (e.g., operations, production, finance, etc.), healthcare and medical cases included. From the different approaches on the demanding task of how to transform human knowledge into computer comprehensible data, the most dominant solution has been applying a rule-based system [3]. Interestingly, the aforementioned research inspected about 300 expert systems from the last 30 years, yet it seems, that none of them addressed the problem of daily lifestyle assessment.

In the treatment of diseases affecting considerable masses in modern societies, changing lifestyle was identified as a key component. Carelessness has a huge impact on life quality, as developing harmful conditions is strongly related to living unruly, unhealthy lifestyles. The Lavinia Lifestyle Application [4] serves as a tool for users to log their daily nutrition and medicine intake, and their physical activity. Analyzing the data acquired in this way, by using the knowledge of dietary experts, could improve the effective assessment of users' lifestyles.

Computer based work, already in the early years of the 2000s, was found to be dominant in developed countries [5]. This extensive use of computers results in workers sitting for most of their shifts [6], but research has shown, that by investigating working environments and improving workplace ergonomics, the negative effects of this prolonged sedentariness can be reduced effectively [7]. Yet, in that case, participants were in direct contact with (ergonomist) experts, which, although desirable, on global scale could be found infeasible and/or unprofitable, so computerizing and automating this procedure could serve as a good alternative.

Section II details the methods used, Section III describes the framework developed, and in Section IV the two modules are presented. In Section V, preliminary results are shown, while Section VI addresses the conclusions and future work.

II. METHODS

A. Expert Systems

There are different approaches on implementing expert systems (case-based reasoning, fuzzy logic, genetic algorithms, etc.), but for lifestyle assessment a rule-based ES is sufficient, as the experts of the related fields (e.g., dietitians, ergonomists) can usually express their knowledge in the form of IF-THEN like rules. Rules are applied on facts (statements describing the current state of the system, and the new events) by an inference engine, to deduce new facts and provide explanation, if needed. An advantage of using such an expert system is that updating the knowledge base can be easily done, as it is separated from the reasoning engine, so changes in it will not affect basic functionality of the system.

The sources of the rules used in the lifestyle management module are dietitian experts who participated in the clinical trials related to the development of Lavinia, as there are numerous different recommendations and standards to otherwise choose from. For evaluating user postures, RULA

(Rapid Upper Limb Assessment) [8], a generally accepted scoring method for measuring physical load on office workers, is selected. One of its advantages is that it rates not just the postures themselves, but also considers how much time is spent in them.

B. Modelling Time

For many problems addressed by expert systems, the temporal relations of facts are not relevant. In lifestyle assessment, however, time has an impact on making decisions: for example, a fact like "the user has exercised today" should be handled differently, whether if it is the first or the 7th occasion in a week (as the latter is a greater achievement). Handling time passing is crucial, as there may be facts that have lost their actuality and thus should be updated or removed, while others may have to be inserted after specific time intervals have passed: a fact like "the user ate fish today" should change to "the user ate fish yesterday" on the next day.

This "time problem" has another aspect: the time concept for logging events is different from the one used by experts. The former is assigning a specific timestamp to every event, while experts tend to refer to events from the present time (e.g., "Yesterday the patient ran 5 km"). To solve this semantic gap, the framework uses relative timestamps (fact ages). When inserted, facts have an age of 0, which then can be updated by aging rules as many times as needed. These rules activate (fire) when given signaling facts (that indicate the passing of a specific time interval) are inserted. In order to allow the usage of various measures of time (e.g., week, day, hour), the framework is currently able to handle two different time dimension configurations (one for each module created). The first one is for applications in which the shortest interval required is one hour, and longest is a week. This case, used in Section IV A, has time units "hour", "day" and "week". The other one is suitable when the minimal interval is one minute, and the maximal does not exceed a day. This setting, applied in Section IV B, offers two units: "minute" and "hour".

C. Validation and Testing

Once a sufficient number of rules have been formulated, their proper validation is needed, by field tests, if possible, or by using Turing test-like blind evaluation, when both the system's and expert's outputs for the same input are evaluated by other experts, without knowing who is performing.

For expert systems, simulation of user behavior is needed to provide the necessary input. Using time configurations allows accelerating this evaluation process: after inserting the relevant facts for a given time interval (minute, day, etc.), a fact stating that the current interval is over can be inserted, and the test can continue with the next one. This way, even data spanning a year can be processed in some minutes.

For the lifestyle management module, former user logs of the Lavinia Lifestyle Application are available and can be used for testing. For the workplace ergonomics part, video recordings from office work surveillance/monitoring could be used for the same purpose.

III. THE FRAMEWORK

From the available expert system solutions, CLIPS (C Language Integrated Production System) [9] was chosen to serve as a basis, as it has already proved its value (e.g., in NASA's space shuttle missions [10], security purposes [11]), and for its advantages such as being a public domain software, having low resource needs and for supporting portability (C code). With regard to the portability offered, the framework is based on C++ language. An overview of the framework developed is shown in Figure 1.

The CLIPS runtime is responsible for evaluating rules and facts. The event dispatcher inserts the incoming facts from the interface into CLIPS and to the database (DB). It also stores the output of CLIPS (facts deducted) in the database, and based on it, forwards any messages to the interface, if needed. The database is not used for only modelling the problem, it serves as a backup on CLIPS' work memory. It can be used for initialization, when a former state of the system is to be reconstructed, and for debugging purposes, to investigate the validity of the reasoning. The main entities of this database are the following:

- *rule*, *fact* and *event* tables – containing the defined rules, facts and events
- *rule_fact* table – storing the connection of facts and the rules that deduced them.
- *rset* and *rule_set* tables – allowing rules to be sorted into groups. This provides the ability to change which rules are currently used. E.g., apply different rules for diabetics and healthy people.
- *rule_gui* table – storing the messages to be displayed, for given rules.

The interface (using Google Protobuf [12]) is for other applications to use, when modifications in the expert system are needed, and to receive its responses. There are two groups of Protobuf messages: *control* and *event*. *Control* messages can be used to manage the expert system, e.g., *INTERVAL_PASSED* "orders" the expert system to age facts by the shortest time unit configured. An *event* can be of two types, *fact* or *consequence*: the former is for inserting new facts (module specific system input), the latter is for outgoing communication (e.g., displaying messages). The structure of Protobuf messages is shown in Figure 2, where the possible fact values are for the lifestyle management module.
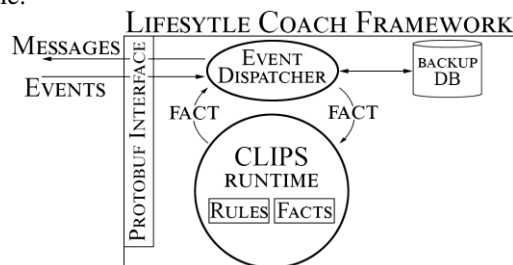

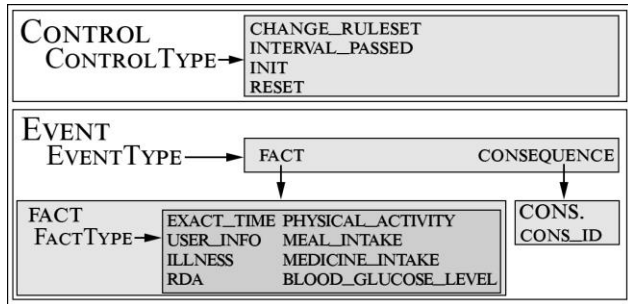Figure 1.   Overview of the system

Figure 2.   Interface message structure (lifestyle management module)

For the work ergonomics module, a similar structure is used, with the same *control*s and *event* types, but of course, it uses different *fact* types that are relevant to the ergonomic evaluation of user behavior.

IV.   APPLICATION DOMAINS

A.   Lifestyle Management

To analyze the user logs provided by Lavinia, an expert system module was developed with the framework presented in Section III, that applies rules formulated by dietitians.

An example for such a rule is "For exercising on every day in the last week, the user is to be complimented". Defining a rule checking the last 7 days for exercises done is simple with this framework: when the sufficient number of facts having the required ages (0, 1, …, 6 days) is found, the compliment is sent. (This, of course, requires logging the exercises and forwarding this information to the system.) To avoid bombing the user with the same message repeatedly (as the notification requirements are met), after the rule has fired and the first compliment is sent, a new fact stating the completion of the feedback is deducted (see Figure 3). This rule, however, is to be removed after a specific time interval, to make complimenting possible again. This, as the new rule by definition has an age when created, is achieved by adding a simple removal rule.

Another rule, requiring a different approach, is "If user's daily fiber intake reaches the recommended value, a compliment is to be sent". As users' goals can differ concerning their weight plan (gaining, losing or maintaining), and with them their corresponding recommended fiber intakes, rules handling all possibilities were created. After each midnight, the recorded intake value is set to zero, and when meals are logged, it is increased accordingly to the food's fiber amount.

```
(defrule physical_activity_whole_week
   (physical_activity_whole_week)
   (not (physical_activity_feedback
         (fact_age_day ?g&:(= ?g 0))))
   =>
   (clips_event_happened 5)
   (assert (physical_activity_feedback))
)
```

Figure 3.   A rule for sending a motivational message

Notifying users when the daily intake is reached is similar in each cases, but the related reactions are distinct: it is either a warning to avoiding additional consumption (maintaining or losing weight) or a compliment (weight gain).

To validate the rules created, former logs of randomly selected Lavinia users were used to simulate real human behavior (see Section V).

B.   Work Ergonomics

The problem of assessing office work ergonomics can be separated into two subtasks: the first is the already discussed problem of translating human knowledge for computers. The second is providing the means for gathering the user input to be analyzed, without requiring active cooperation from users.

In case of ergonomic assessment, rules focus mostly on the users' body postures, usually with regard to the time spent in those poses. This means concerning postures both for the whole body (e.g., "the users should not sit in one place for too long"), and in more detail, like "for most of the time, users' forearms should be properly supported", or "the users should not spend too much time with their heads tilted (cradling a phone)". Of course, as previously mentioned, time concepts such as "too much", "too long", etc., are incomprehensible for computers, so ergonomist experts are needed to define more precise time intervals. Moreover, they are the ones who can specify what is an acceptable posture and what is not for rules such as "the users should sit with their back held properly". However, this precision would prove useless, if the other subtask, collecting posture data, is not solved correctly.

A trivial approach for monitoring users' postures is using some camera equipment. To precisely detect user position or posture, however, a "traditional" 2 dimensional (2D) device is insufficient, as in this case, 3 dimensional data is required. Of course, using more than one 2D camera could solve this problem, but applying a single sensor with the required functionality is preferable. Such a device is the Microsoft Kinect v2, that provides video (colored and infrared) and depth data streams, as well as a built-in feature for body recognition and tracking (25 skeletal joins per person, up to 6 people) [13][14].

The accuracy of Kinect in office monitoring was addressed in [15], showing that its tracking capabilities are acceptable, but whether the received data is usable for ergonomic evaluation or not, was not mentioned. To investigate this, a test software, measuring and displaying the acquirable information of user behavior, has been created, and is currently being evaluated by ergonomists.

Parallel to this, with the framework developed, a basic expert system module was created, in order to validate if it can react properly to simple workplace related situations or not. For this reason, some basic ergonomic rules were formulated, these are detailed in Section V.

V. RESULTS

In total, 29 rules were formulated so far in the lifestyle managing module: 6 of them are automatically generated by the framework for aging facts, the rest serve for lifestyle assessment. The implemented statements given by dietitians were:

- When users log their fasting blood glucose level, they are to be rewarded.
- When users log their insulin dosage, they are to be rewarded.
- Walking 30 minutes a day should be rewarded.
- Users should be complimented if, for the last week, they exercised every day.
- If the user reached the recommended daily fiber intake, a compliment is to be sent.
- The users are to be complimented, if their BMI (Body Mass Index) drops below 25.
- Logging meals containing fish dishes on two different days in the last week is to be complimented.

The tests have shown that the already defined rules provide the required functionality and work properly, so work on implementing additional rules to cover a wider part of lifestyle assessment can begin. Moreover, trials of running the framework on smartphones were successful, and have shown that it is possible to use this lifestyle assessing system on mobile devices.

The work ergonomics module was tested in a similar fashion, but as evaluation of the data acquiring sensor is still in progress, plain concepts and lenient constraints were used in rules like

- After 90 minutes of continuous sitting, the user is to be advised to stand up/take a walk.
- After 3 hours of continuous sitting, the user is to be compelled to stand up/take a walk.
- If for at least half of the time in the last 60 minutes, the angle of the user's back and the vertical position was more than 30 degrees, a warning is to be sent.
- If for the last 60 minutes, it occurred more than 3 times that the user spent more than 3 minutes with their head rotated more than 30 degrees (compared to the vertical position), a warning is to be sent-

As in the case of the other module, tests have proved that the basic functionality of this module is satisfactory, and can be used for implementing concepts regarding work ergonomics, however, it is clear that more precise intervals should be used in discriminating proper and improper postures.

Initial results on Kinect's applicability seem to confirm that the device is suitable for ergonomic evaluation, but only after some preprocessing done, as in some occasions, false body detections and strange body pose predictions have been observed. Changing the position and orientation of the device was found to have a notable effect on how accurate the readings are, which correlates to the findings of Wiedemann et al. [15].

VI. CONCLUSION AND FUTURE WORK

This paper presented a framework for creating expert systems for lifestyle assessment, and two examples for its application domains were introduced.

The tests show the developed framework and the modules to be promising, however, further study has to be done on how user behavior can be assessed more thoroughly, and on what the related system reactions should be (what other rules to implement). Based on these findings, if needed, the framework itself should be improved accordingly.

For the lifestyle management module, apart from additional rules, further improving the method for providing positive feedback on Lavinia users' behavior (what the messages should be) is also important, as this can have a great impact on their motivation and success.

The implementation of the RULA-based rule set is in progress, and a total of 30-40 rules is expected to cover all significant aspects of work ergonomics. The validation of the developed module, as well as its rule-base, is to be completed in early 2018.

In both testing procedures of the work ergonomics module, the idea of having the system running on a different computer than of the user's has emerged. This would save the user's device from providing the computational requirements of the data processing, could strengthen error resistance (e.g., protection from power outage related damage) and would allow additional security measures (limit access to the system).

However, an additional personal computer in the work environment might be found unappealing (e.g., it requires more space, cabling, etc.). A solution to this problem, and also to the proper placing of the monitoring sensor, could be using an "intelligent workstation": a mechanical desk, embedded with a single-board computer capable of executing the tasks related to data acquisition and expert system management, with a structure that makes it possible to install the sensor in an optimal position. Moreover, other useful features could also be implemented, e.g., motorized height adjustment of the desk or a self-adjusting adaptive desk lamp. On how these could be efficiently implemented, and what other handy utilities could be used, further research is needed.

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