Wellness Concepts Model use and effectiveness in intelligent knowledge authoring environment

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Abstract Intelligent recommendation systems have high impact on users to adopt healthy routines towards the optimal health and wellbeing. The wellbeing recommendation and decision support systems need up-to-date wellness knowledge for effective recommendations to the users. Lack of evolutionary knowledge base is the most prominent barrier in the effectiveness of wellness recommendation system and its applications for assisting in healthier life choices. Domain experts can transform their knowledge into the evolutionary knowledge base of intelligent recommendation system, when they have access to an intelligent and supportive knowledge authoring environment. We have proposed a system that provides an intelligent and supportive knowledge authoring environment with the help of scalable wellness concepts model (WCM). WCM helps in contextual selection of concepts and their values set using Intelli-sense approach during the rule creation. The use of WCM, in knowledge authoring environment, enhances experts' performance and decreases the chance of errors in wellness knowledge creation. It maximizes the concepts recall ratio of domain experts and provides guidance to some extent during rule creation process. We evaluated our system using user-centric evaluation by 6 domain experts. Each domain expert created 5 rules, containing 2 simple and 3 complex using the proposed system. The results suggested that the proposed system has user-satisfaction level up to 80.42%.

Keywords: Wellness; Wellness Concepts Model; Intelligent Environment; Knowledge Authoring; Recommendation system

1 Introduction

Wellness has broader scope than health-care, health-care considered as part of the wellness domain. In illness-health-wellness continuum [1], individuals mainly focus

on positive aspects of health and wellness sides to protect from illness. In the past few decades, the number of counseling approaches, in health and wellness domains, has grown exponentially [2, 3]. In current technological era, intelligent recommendation systems play very important role in recommending and counseling the users about healthier life. These systems depend on evolutionary knowledge base and which is considered as core component of the system [4, 5]. Knowledge acquisition is a challenging task and also a key barrier to adopt evolutionary knowledge base expert systems [6]. This is because of the cumbersome and unsystematic interaction between knowledge engineers and the domain experts.

Knowledge engineering "bottleneck" in expert systems adoption has encouraged the knowledge acquisition researchers to provide a controlled and assistive knowledge authoring environment to domain experts without doing extensive tasks [7]. In addition to interactive and easy to use features of authoring environment, the knowledge should be shareable, interoperable, and easily integrateable to heterogeneous databases of the legacy systems [6]. All the three aspects of knowledge acquisition; easiness, shareability and interoperability, can be achieved by utilizing standard data models and standard terminologies [6, 8]. Domain experts feel comfort with standard terminologies in creating knowledge rules. Standard terminologies such as SNOMED CT [5, 10] and data model standards like Virtual Medical Record (vMR) [9] are designed for use in decision support systems. The list of standards in clinical domain is not limited to only these standards. Unlike clinical domain, wellness domain is lacking in standards and there exist neither the data models nor the terminological standards.

Without controlled vocabulary in authoring environment, domain experts utilize their own concepts that may differ from one expert to another. Therefore, inconsistency prevails in the knowledge rules created by different experts with their own terminologies. This lack of conceptual consistency leads to the interoperability issue of knowledge base with the legacy systems [6]. Additionally, the controlled vocabulary also helps the experts to maximize the recall of concepts during the rule creation. Experts feel comfort with controlled vocabulary and it enhances the performance of the experts. In similar way, the controlled vocabulary in the form of contextual selection of concepts [11] reduces the chance of errors during the rules creation. In current study, we take initiative to propose wellness concepts model (WCM), based on physical activities and nutrition domain, verified by the domain experts. This WCM is incorporated in Intelligent Knowledge Authoring Environment and used by the experts for rules creation. This WCM is a way towards standardization and controlled terminology in the wellness domain. In our proposed system, WCM facilitates domain experts to create knowledge rules using contextual selection of concepts.

Last two decades of 20th century, the wellness has been defined as a new paradigm in the health-care [12]. Many researchers have proposed different wellness models for different purposes; one of the popular wellness models is *The Indivisible Self* [3], which we have selected as a baseline for our proposed WCM. We have derived our WCM from the five second-order factors of *The Indivisible Self*. We extended the model in three basic areas *Essential*, *Physical*, and *Nutrition*. The main reason behind

selecting these three components is the focus of evolutionary knowledge base for an innovative personalized health and wellness recommendation system called Mining Minds [13][14]. Mining Minds is a novel framework that focuses on digital health and wellness paradigms to enable the provision of personalized health and wellness support [13, 14, 15]. Therefore, our proposed knowledge authoring environment primarily focuses on the knowledge of users' physical activities, health status, and nutrition components in the wellness domain. Other components of wellness domain like mental health, spiritual and social life can easily be integrated with WCM for intelligent recommendations in corresponding domains.

The proposed knowledge authoring environment allows the domain experts to utilize the WCM concepts for keys as well as values in all facts of rules. The experts can easily select their desired concepts from the WCM tree in the rule editor, while the corresponding possible values set is shown in the immediate window as Intelli-sense. Therefore, the authoring environment provides the controlled vocabulary of wellness in two different ways like WCM tree and Intelli-sense window.

2 Related Work

2.1 Wellness Concepts Model (WCM)

Ardell, D. B. [16] have proposed definition of wellness and model for high level of wellness in nutrition knowledge, physical fitness, stress management and environmental awareness. In same way, Hettler B. [17] also categorized the wellness model in high level of concepts like physical, nutrition and social categories. Both of these high level model are considered as pioneer models in wellness domain.

A theoretical model based on counseling theory called *Wheel of Wellness*, was first introduced in early 1990s by Sweeney and Witmer [18][19]. The authors have identified a number of characteristics that are related to the healthy living, quality of life and longevity. They organized these characteristics according to life tasks, friendship and love. The original *Wheel of Wellness* model has seven sub-tasks in the life tasks. According to this model, the life forces that effect an individual's life are family, religion, education/industry, media, government, and community.

After an extensive survey, Myers and Sweeney [3] have proposed an evidence-based model of wellness *The Indivisible Self*. The authors have realized that the structure of *Wheel of Wellness* should be re-examine due to hypothesized relationships among its components and the complex structure of it. *The Indivisible Self* has proposed a higher-order wellness factor, which is based on the Adler's [20] theory of holism, the indivisibility of self. Five main concepts are considered as second-order factors; *Essential Self, Social Self, Creative Self, Physical Self*, and *Coping Self*. These second-order factors are further categorized into 17 sub components. This model provides strong support for basic Adlerian concepts related to holism and the indivisibility of human existence is supported by this research findings. In our proposed WCM, we have considered this model as fundamental

concepts in second-order of hierarchy. We enhanced wellness model by adding more concepts based on extensive literature with the help of a team of experts.

2.2 Knowledge Authoring Environment

There are knowledge authoring tools available in clinical domain, while specifically wellness domain lacks these tools. A multiple-method knowledge acquisition shell is proposed in [21] that generates knowledge acquisition tools without a specific model of problem solving. The system provides very generic environment to create knowledge for multiple domain, but domain expert needs help in technical aspects to formalize domain knowledge. In this case, the domain experts have dependency on knowledge engineers to build a domain knowledge base.

A collaborative ontology editor and knowledge acquisition tool WebProtege is proposed by Tudorache, T et.al. in [22]. The system was built using the existing protégé infrastructure that supports collaboration on the backend side. The authors have developed a useful ontology editor for knowledge acquisition, but this editor is difficult to use for domain experts without semantic web knowledge to create domain knowledge. Dustin Dunsmuir et al. have proposed a system in [23], which enables clinicians to create knowledge rules without the help of knowledge engineers and programmers. The system is based on the “pattern and outcome" approach and works in the domain of anesthesia. However, its scope is limited and difficult to extend to other domains. This system creates rules directly in XML files; therefore, physicians are involved with XML files, which require the tedious extra task of XML training.

3 Methodology

3.1 Wellness Concepts Model (WCM) Paradigm

The focus of healthcare domain is transforming from disease to wellness, and wellness domain is shifting towards user centric model with innovative platforms [13]. The Mining Minds [13, 15] is an innovative platform that exploits digital health and wellness paradigms to the end users by providing wellbeing services and recommendations. Mining Minds mainly focuses on the health and wellness recommendations and guidelines. The structure of Mining Minds is divided into different layers and each layer is responsible to perform its related activities. Knowledge Curation Layer (KCL) [15] is one of these layers is designed to maintain the evolutionary knowledge base for the essential requirement for intelligent recommendation services. In KCL, our proposed Knowledge Acquisition Tool (KAT) facilitates expert to transform their knowledge and experience in to computer interpretable knowledge base. The KAT currently emphasizes on physical activities and nutrition knowledge for recommendations. Using KAT, the physical instructors and nutritionist transforms their knowledge utilizing the concepts of physical, nutrition, and user’s essential information. These concepts are part of WCM and are related to each other through different relationships. Figure 1 illustrates the

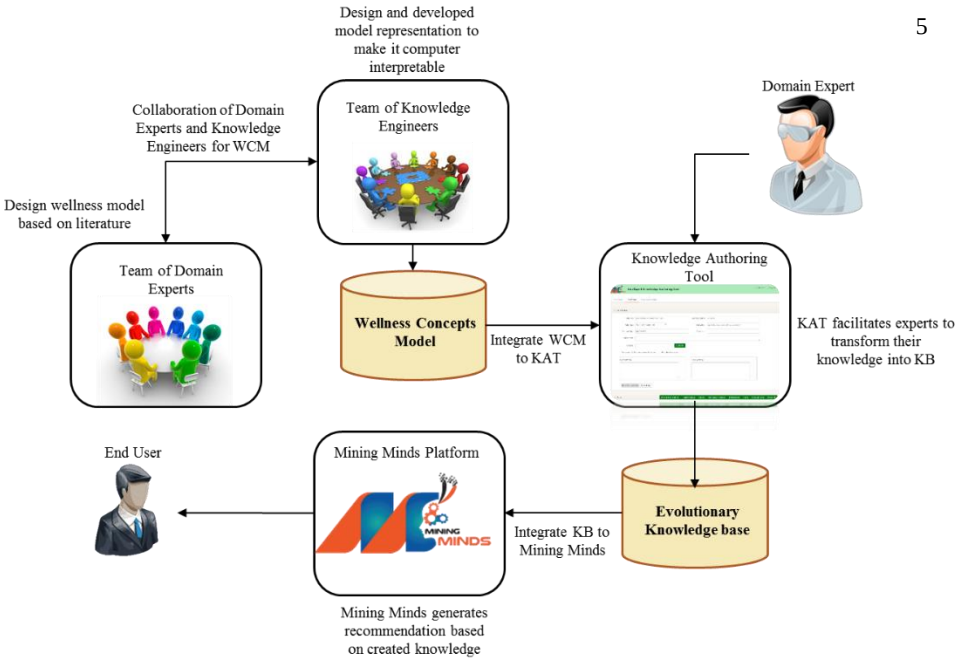

Figure 1: Integration of Wellness Concepts Model and Knowledge Acquisition Tool paradigm

development and integration paradigm of WCM with KAT to evolve the wellness knowledge for Mining Minds.

A team of domain experts including 2 nutritionists and 3 physical instructors designed the conceptual model and provided the higher level blueprint of WCM. A collaborative study between the teams of domain experts and knowledge engineers took place to initialize design and implementation of WCM. The knowledge engineers' team provided the identified relationships among the concepts represented the model in ontological format for computer interpretation. The domain experts' team validated the design and verified the WCM implementation. Eventually model is persisted in the repository. This WCM repository is integrated to KAT, which facilitates experts to evolve the knowledge base in user-friendly manner.

3.2 Wellness Concepts Model (WCM) Design

The *Indivisible Self* [3] provides very comprehensive evidence-based wellness model, which we selected as a core model for this study. We modified the model according to the health and wellness requirements of a recommendation system, specifically for physical activities and nutrition domains. The Indivisible Self model is composed of the second-order factors including Essential, Creative, Coping, Social, and Physical Self. The proposed WCM model extends the second-order hierarchy with multiple level of depth in Creative, Essential, and Physical components based on the nature of components. The Creative category contains Thinking, Emotions, Control, Positive Humor, and Work. Usually the wellness recommendation systems use emotion and work related information of the users. Therefore, we extended the Emotion and Work

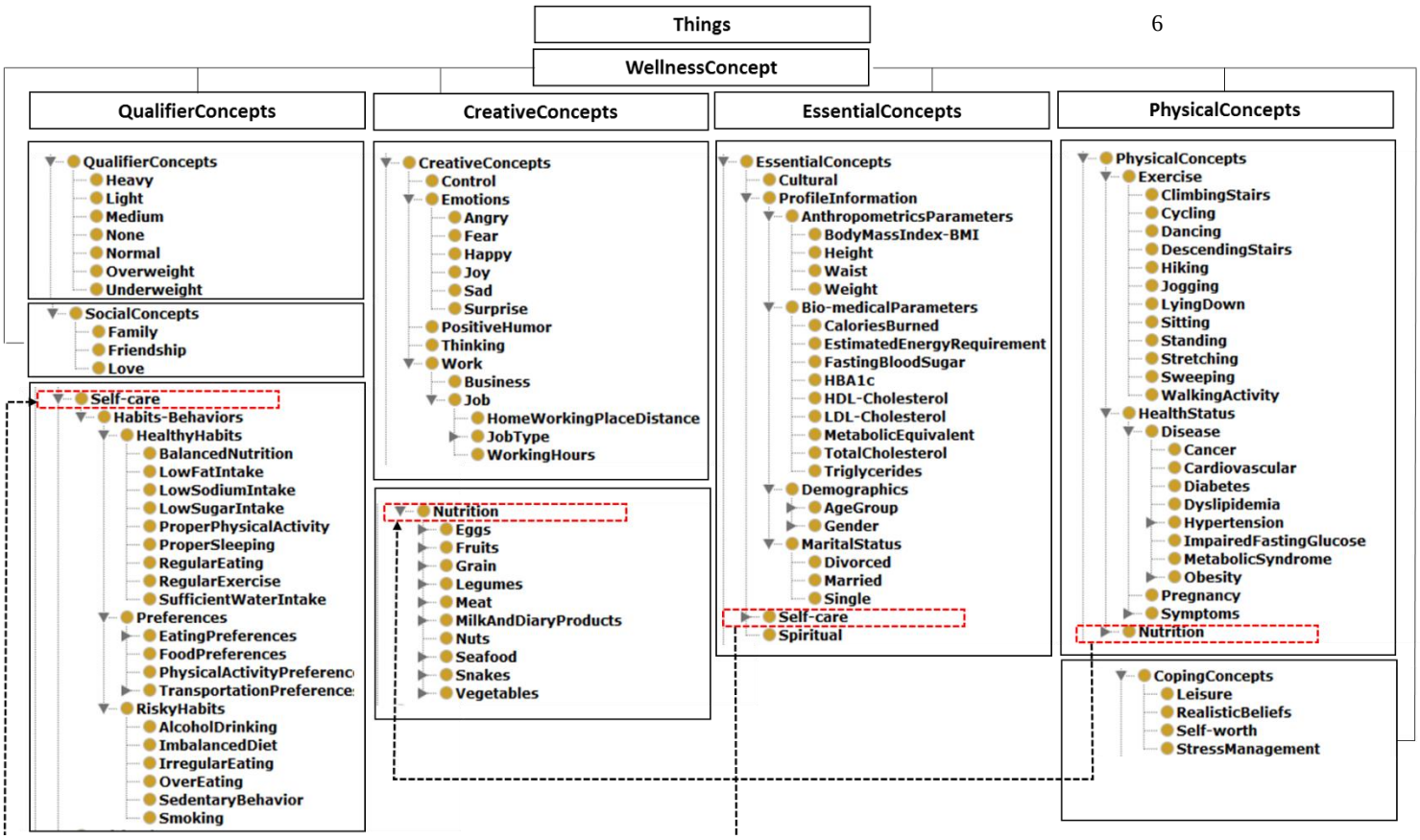

Figure 2: Partially represented Wellness Concepts Model (WCM)

categories under the Creative hierarchy. In same way, we have added many other concepts under the Essential category as shown in Figure 2. For instance, under the Profile Information, we put the demographic information, anthropometrics parameters, and bio-medical parameters. Under Self-care, which is subcategory of Essential, we have related all the behaviors and habits of users that play important role in self-care, like risky habits, healthy habits, preferences in food, activities, hobbies, and transportation.

In Physical self, we added Health Status as subcategory and related it to diseases, symptoms, and other health related concepts. We put concepts that belong to physical activities under the exercise hierarchy while diet concepts under the nutrition hierarchy. Health status, physical activities, and nutrition are the main focus of wellness recommendation systems. We have introduced a new category qualifier concepts in second-order factors, which contains all the concepts that illustrate possible values set of other concepts. For instance, normal, heavy, light are some possible values set for dinner, lunch, and breakfast. We have provided maximum

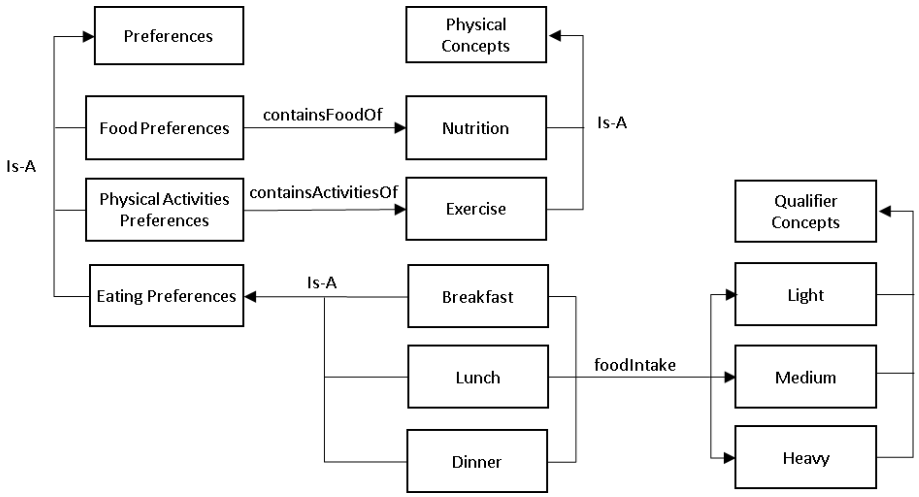

Figure 3: Attribute relationships in WCM

semantics in all these concepts that are usually use in wellness recommendations. For instance, each user has some preferences in food, physical activities, transportation, and eating time. New concepts can be plugged-in easily in a related hierarchy because of the flexible hierarchical structure of the model. Figure 2 shows wellness concepts model hierarchies partially, while figure 3 demonstrates the attribute relationships among some concepts. For instance, the three attribute relationships a) *containsFoodOf* b) *containsActivitiesOf* and c) *foodIntake* are used to connect different concepts. The a) relates food Preference with Nutrition, b) relates Physical Activities Preferences with Exercises, and c) *relates* Eating Preferences (Breakfast, Lunch, and Dinner) with Qualifier Concepts (Light, Medium, Heavy).

3.3 Implementation of WCM Integrated KAT

In figure 4, we present the implementation architecture of our proposed WCM integrated Knowledge Acquisition Tool (KAT). It consists of six sub-components Domain Model Manager, Rule Editor, Situation Event Manager, Knowledge Transformation Bridge, Knowledge Base and Knowledge Sharing Interfaces.

Domain Model Manager: This component is responsible to manage the wellness model. It loads the WCM into the Rule Editor to use in rule editing activity.

Rule Editor: As a core component of KAT, rule editor provides a user-friendly environment to domain expert to create knowledge rules. The knowledge rules represented in form of unordered production rules. The rule base reasoning (RBR) used to generate final recommendations to end users. It comprises of five further sub-components to perform distinct functionalities. ***Model Loader*** is in charge of loading WCM concepts into the rules editor in tree structure for easy selection of desired concepts. This sub-component shows all the concepts in a single tree or sub-tree based on the top categories like Profile Information, Diseases, and Physical Activities. The ***Intelli-sense Manager*** provides a list of related concepts which are used to facilitate the experts to choose the desired value from the list. For instance, when

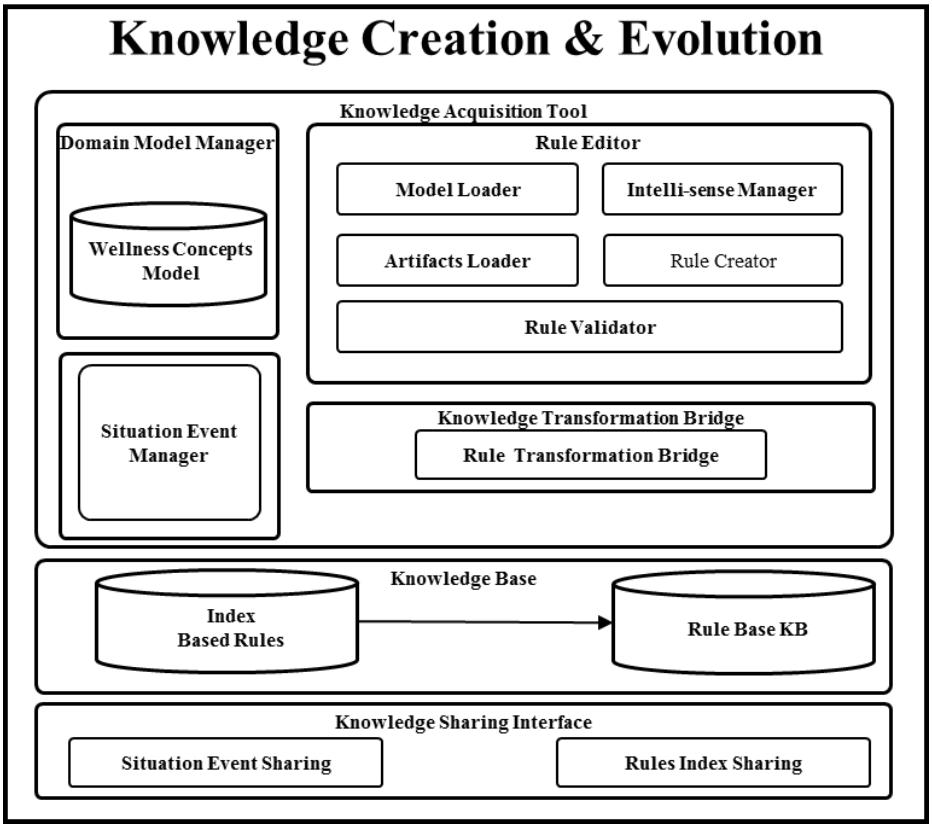

Figure 4: Architecture of WCM integrated KAT

expert wants to write Physical Activity = Sitting, the possible values set for Physical Activity are reflected to appear such as; Standing, Sitting, Walking, Jogging, and others. A separate inner Intelli-sense window is shown to reflect all possible values. ***Artifacts Controller*** fetches the operators into the Rule Editor and facilitate experts to select required operators from the list. The ***Rule Creator*** module creates the rule from all facts and conclusion created by experts in conditions and conclusion parts. It creates the hierarchy of conditions and conclusion in the created rules. The ***Rule Validator*** validates the rule and finds the duplications and conflicts of the new rule with the existing rules in the knowledge base.

Situation Event Manager: Some rules may consist of some salient features that should monitor by the system as events, those features are called situation events. Whenever an abnormal situation occurs, the system generates recommendation and passes as an alert to the user. It facilitates expert to identify and select the desired facts as situation event.

Knowledge Transformation Bridge: This module transforms plane rule into a computer executable format. We use relational schema representation for persisting rules in the knowledge base.

Knowledge Base: In knowledge base, we have two repositories one for persisting the whole rules as ***Rule Base KB*** while the second repository as ***Index Based Rules*** for persisting the situations events in rules. These repositories are closely coupled to each other based on identifiers of situations and rules.

Knowledge Sharing Interfaces: This component consists of two types of sharing interfaces. ***Situation Event Sharing*** interface shares the situation events with monitoring systems to observe the abnormal situations of the users. While ***Rule Index Sharing*** interface is responsible to share the knowledge rules with reasoning engine of the recommendation system.

4 Results and Evaluations

The main objective of WCM integration with knowledge acquisition tool is facilitating domain experts to transform and represent their knowledge to computer interpretable knowledge base. When domain experts are satisfied and comfortable in knowledge acquisition then adoption of wellness recommendation systems will be increase. Therefore, we evaluated the proposed WCM integrated KAT from domain experts to assess their satisfaction over the claimed facilitation of WCM augmented knowledge authoring environment.

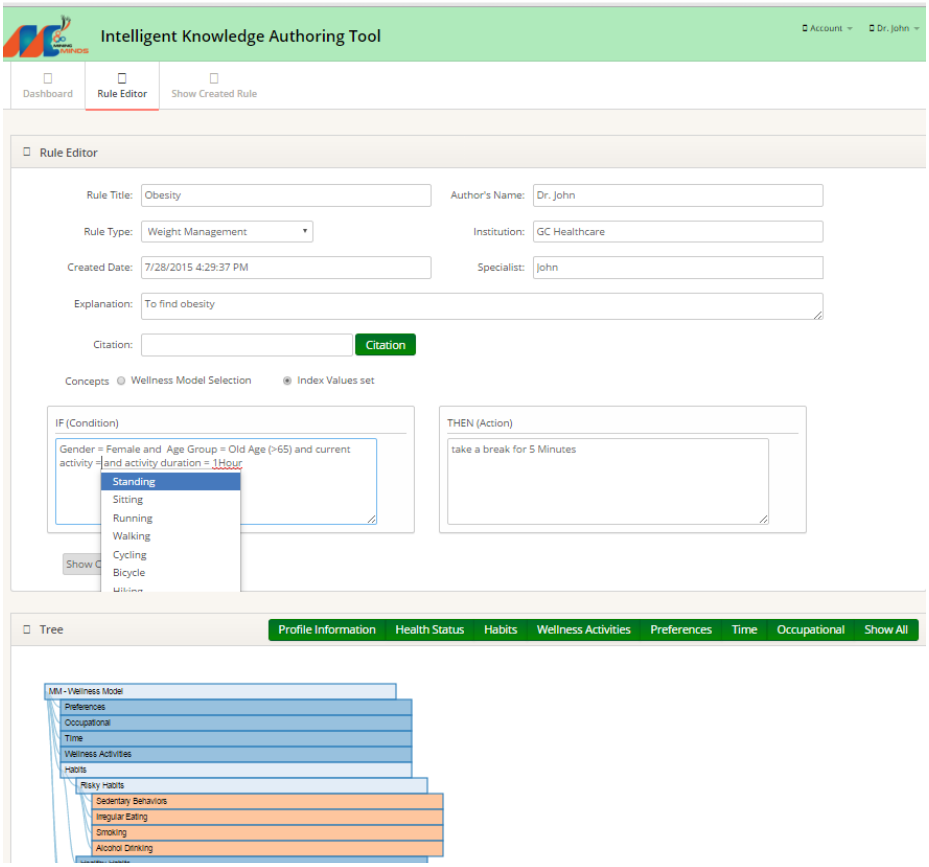

Figure 5: Rule Editor

Experimental Setup: a) We provided the developed knowledge acquisition tool to the domain experts. Figure 5 shows the main Rule Editor of the system that we deployed on the web server. b) In order to easily understand the usage of authoring environment, we also provided the system manual. c) A visual representation of WCM is provided in a graphical format to understand the hierarchies of concepts. d) A set of questions is provided in a questionnaire form. Eight of the questions in the questionnaire are related to the ; (i) organization of the information, (ii) concepts of WCM, (iii) performance and help of WCM in Rule Editor, (iv) coverage of desired concepts in WCM, and (v) user-friendliness of the system. e) Overall six domain experts are assigned including two physical instructors, two nutritionists, and two nurses to evaluate the system on the basis of questions.

During experiment session, each domain expert created five rules in corresponding fields using their experience and knowledge. After knowledge creation, each domain expert provided answers to the relevant questions in our provided questionnaire. Each question has 4 possible answers and we have assigned a weightage to each answer as shown in Table 1 based on the methods and protocols suggested in [24].

We evaluated the user satisfaction level based on the domain experts' feedback. And users' satisfaction level at average 80.42% has recorded. In Table 2, the domain experts' feedback (in percentage) is illustrated to each question. We first found out the average values for each question and then we calculated the system performance by determining the overall average value (80.42%) from the averages of individual questions.

Table 1: Possible answers' weightage

Question Evaluation Criteria	Weightage (%)
Highly Satisfied	100
Satisfied	80
Less Satisfied	60
Not satisfied	40

Table 2: Domain Experts' feedback

User Satisfaction (%)								
Evaluators	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Physical Instructor - 1	80	60	100	80	80	80	80	60
Physical Instructor - 2	100	80	80	60	80	80	60	100
Nutritionist - 1	80	100	80	80	100	80	80	80
Nutritionist - 2	100	60	100	80	80	100	60	60
Nurse - 1	80	80	80	100	80	80	60	80
Nurse - 2	60	60	80	80	100	80	100	80
Average	**83.33**	**73.33**	**86.67**	**80.00**	**86.67**	**83.33**	**73.33**	**76.67**
Total Average	**80.42%**							

5 Conclusion and future work

Every individual intend healthier life, which is possible with healthier physical activities and balanced diet. Wellness model is run by these categories. Without evolutionary knowledge base, a recommendation system is difficult to adopt. Our proposed intelligent knowledge authoring environment is beneficial to create evolutionary knowledge base with the use of a comprehensive wellness concepts model. It provides user-friendly environment to author wellness knowledge by domain experts without knowledge engineers intervention.

Currently, we have validated knowledge rules with respect to duplication and conflict of rules, but in future we will also focus on the semantic validation of rules that will enhance satisfaction level of domain experts.

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