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Multimodal hybrid reasoning methodology for personalized wellbeing services

Rahman Ali [a], Muhammad Afzal [a], Maqbool Hussain [a], Maqbool Ali [a], Muhammad Hameed Siddiqi [a], Sungyoung Lee [a,*], Byeong Ho Kang [b]

[a] Department of Computer Engineering, Kyung Hee University, Seocheon-dong, Giheung-gu, Yongin-si 446-701, Gyeonggi-do, Republic of Korea
[b] Department of Computing and Information Systems, University of Tasmania, Hobart, Tasmania 7005, Australia

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ABSTRACT

A wellness system provides wellbeing recommendations to support experts in promoting a healthier lifestyle and inducing individuals to adopt healthy habits. Adopting physical activity effectively promotes a healthier lifestyle. A physical activity recommendation system assists users to adopt daily routines to form a best practice of life by involving themselves in healthy physical activities. Traditional physical activity recommendation systems focus on general recommendations applicable to a community of users rather than specific individuals. These recommendations are general in nature and are fit for the community at a certain level, but they are not relevant to every individual based on specific requirements and personal interests. To cover this aspect, we propose a multimodal hybrid reasoning methodology (*HRM*) that generates personalized physical activity recommendations according to the user's specific needs and personal interests. The methodology integrates the rule-based reasoning (*RBR*), case-based reasoning (*CBR*), and preference-based reasoning (*PBR*) approaches in a linear combination that enables personalization of recommendations. *RBR* uses explicit knowledge rules from physical activity guidelines, *CBR* uses implicit knowledge from experts' past experiences, and *PBR* uses users' personal interests and preferences. To validate the methodology, a weight management scenario is considered and experimented with. The *RBR* part of the methodology generates goal, weight status, and plan recommendations, the *CBR* part suggests the top three relevant physical activities for executing the recommended plan, and the *PBR* part filters out irrelevant recommendations from the suggested ones using the user's personal preferences and interests. To evaluate the methodology, a *baseline-RBR* system is developed, which is improved first using ranged rules and ultimately using a *hybrid-CBR*. A comparison of the results of these systems shows that *hybrid-CBR* outperforms the *modified-RBR* and *baseline-RBR* systems. *Hybrid-CBR* yields a 0.94% recall, a 0.97% precision, a 0.95% *f*-score, and low *Type I* and *Type II* errors.

1. Introduction

An individual's healthy lifestyle impacts the overall health of a population and results in a healthier society [1]. Without a healthy lifestyle, *i.e.*, proper diet, exercise, and controlled body mass index, individuals are prone to various diseases [2] that include lifestyle as an important cofactor [3]. Adopting physical activity is one of the key responses of individuals that helps in promoting a healthier lifestyle [4]. Similarly, wellness guidelines and automatic wellness recommendation systems play roles in public health promotion. These systems provide support for wellness experts in recommending the appropriate physical activity to individuals according to their personal requirements [5]. A healthier lifestyle involves a balanced combination of physical activity, mental behavior, and social interaction with other community members [6–8]. In this study, we focus on the physical activity aspect of a healthier lifestyle. We also focus on the development of a physical activity recommendation system to motivate users to keep their life active by involving themselves in various types of physical activities. Traditional physical activity recommendation systems provide general guidelines in the form of recommendations, which do not provide user-centric recommendations. To fulfill the

* Corresponding author. Tel.: +82 1073451441; fax: +82 31 202 2520.
E-mail addresses: rahmanali@oslab.khu.ac.kr (R. Ali), muhammad.afzal@oslab.khu.ac.kr (M. Afzal), maqbool.hussain@oslab.khu.ac.kr (M. Hussain), maqbool.ali@oslab.khu.ac.kr (M. Ali), siddiqi@oslab.khu.ac.kr (M.H. Siddiqi), sylee@oslab.khu.ac.kr (S. Lee), byeong.kang@utas.edu.au (B. Ho Kang).

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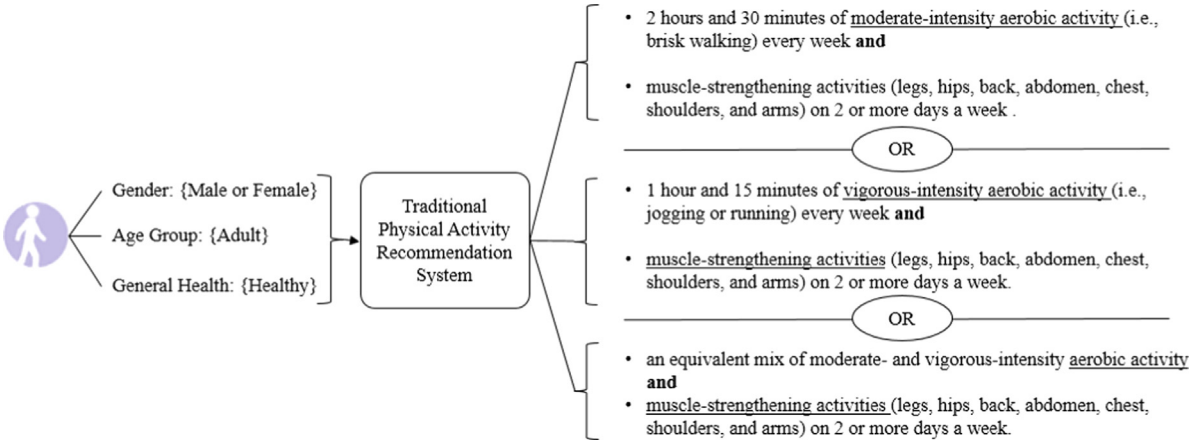

Fig. 1. General physical activity recommendations adopted from the Center for Disease Control and Prevention (CDC) guidelines [9].

personal needs of different users, a personalized physical activity recommendation system is required.

We illustrate the concept of personalized physical activity recommendation using an example in which an overweight, 30-year-old person affected with asthma is interested in personalized physical activity recommendation. The goal is to recommend an appropriate physical activity to this person according to his health needs as well as personal interests. If the recommended activity reflects his requirements, then it will be accepted; otherwise, it will be rejected. Existing physical activity recommendations, proposed by *CDC* [9], *WHO* [10], *AHA* [7], among others, recommend general physical activity for the whole community of users. These recommendations are abstract and exploit limited personal information of the users. An example of the *CDC* recommendations is shown in Fig. 1.

Fig. 1 shows that gender, age and health conditions are taken into consideration while suggesting options of physical activities. The following important questions arise:

A. Are the suggested recommendations appropriate for the person considered in the example?
B. Are the provided recommendations based on the user personal information (*e.g., BMI*), health, physical activities routines and preference list?

The answers to these questions are 'no', which mean that the system provides general guidelines and the user has to look into his personal information, daily routines, and preferences and choose appropriate physical activity for himself. Generally, this should not be the case and the recommendations shall reflect the person's specific needs. The system needs to be intelligent enough to first reason on the user personal profile information and calculate the user's weight status, target weight (goal status), and plan to achieve the goal. Based on these assessments, appropriate physical activity should be recommended according to the user current and past routines of activities and preference list.

To achieve the above stated goal, we are working on a personalized wellness platform called Mining Minds[1] [11] (see Section 3). Mining Minds is a collection of services, tools, and techniques for collaboratively investigating and analyzing the user's personal profile and daily routines for providing personalized wellbeing services. These services are generated by executing knowledge rules using the Mining Minds (*MM*) reasoning engine. This study focuses on the reasoning methodology adopted by the reasoning engine to generate daily physical activity recommendations. A multimodal hybrid reasoning methodology (*HRM*) is proposed, which plays an important role in interpreting the user's profile, physical activity routines, and personal preferences for generating personalized physical activity recommendations. *HRM* integrates the rule-based reasoning (*RBR*), case-based reasoning (*CBR*), and preference-based reasoning (*PBR*) methodologies for enabling the reasoning engine to personalize the recommendations. *RBR* of the proposed *HRM* exploits domain knowledge rules extracted from guidelines, *CBR* exploits implicit knowledge obtained from experts' past experience (successful cases), and *PBR* exploits users' personal preferences and interests to ensure accurate and personalized recommendations. The key ideas of *HRM* include the following: (i) exploitation of the diverse knowledge sources for personalized wellbeing recommendations using the integration of multiple reasoning methodologies, such as *RBR*, *CBR* and *PBR* in a linear combination to form *HRM*, (ii) reducing the bottlenecks of traditional single reasoning methodologies, which exploit only single knowledge sources for generating a single service at a time and (iii) enabling the generation of specific, relevant and personalized physical activity recommendations according to the user's specific requirements.

To validate the proposed *HRM*, a weight management scenario is considered, and a set of experiments are performed. The use of *HRM* for weight management is an innovative idea that guarantees specific and precise personalized physical activity recommendations. It is important to mention that our prescription of physical activities only focuses on healthy adults and not on people with disabilities, women who are pregnant and people who have medical complications.

The rest of the paper is structured as follows. Previous research is summarized in Section 2. In Section 3, an overview of the *MM* platform is provided. In Section 4, the proposed *HRM* is discussed from architectural, knowledge acquisition and reasoning perspectives. In Section 5, the experiments are performed, and the system is evaluated based on a weight management scenario. In Section 6, a discussion on the methodological aspects of the paper, different challenges faced and limitations of the approach is provided. Section 7 concludes the work performed and outlines some possible future extensions. Section 8 acknowledges the contributors and financial sponsors.

2. Related work

Human experts are limited in number and expensive in terms of healthcare and wellness services provided. Healthcare decision

[1] http://www.miningminds.re.kr/