User Profile Ontology to Support Personalization for E-Coaching Systems

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ABSTRACT

In recent years, e-coaching systems have played an increasingly significant role in promoting a healthy lifestyle and positive behavior change. Research efforts have grown to provide more useful and effective e-coaching systems for research or other purposes. The implementation of e-coaching systems resulting from these efforts utilizes several techniques including Artificial Intelligence (AI) methodologies. This study proposes a personalised approach to support an e-coaching system that is tailored to the user's characteristics. A key component of this system comprises an ontological model of the user profile. The objective of this research was to propose an ontology that is able to collect and analyze the user related information as well as customize the profiles with the most appropriate coaching recommendation or materials. The ontology employed in this study was developed using the OWL (Ontology Web Language), a knowledge representation language for authoring ontologies. The effectiveness of this approach will be enhanced by filtering the information that was presented to the users.

KEYWORDS

Ontology engineering, User profile, Knowledge representation

1 INTRODUCTION

Researchers have started to explore the potential benefit of coaching to facilitate the promotion of healthy behaviors and help individuals to achieve health-related goals[13]. Coaching that is applied in health domain is often referred to as *health coaching*, consequently defined as the practice of the health education and promotion within a coaching context to improve the well-being of individuals and to facilitate the achievement of their health-related goals[8].

With the proliferation of digital technologies, coaching has taken place as a potential strategy that was used in technologies which facilitate healthy behavior change. E-health or electronic health is the working definition for the use of Information and Communication Technologies (ICTs) to support or improve health and healthcare[26]. These technologies were used in promoting physical activity[10], providing personalized feedback for eating behavior[23], as well as other clinical domains such as treating insomnia[2]. E-coaching systems were inspired, firstly, by the need to model the human "intelligence" in a technology which can continuously monitor its users' activities and surroundings, detects situations where intervention would be desirable and offers prompt assistance [19]. Previous works in e-coaching systems are based on a one-size-fits-all approach to delivering the coaching actions irrespective of the user's conditions, goals, knowledge, abilities, or preferences. This problem of delivering the same coaching actions to all users can be addressed by using personalization strategies to adapt the coaching process or plan to the user's requirements. Therefore, one of the key issues in the next generation of e-coaching systems is to identify the user's characteristics(e.g., health conditions, goals). However, these systems are limited in their ability to provide adequate personalization of the e-coaching activities. Thus, this raises the challenge of how to design for a user profile model which is lacking in current e-coaching systems.

In the light of the above challenges to current e-coaching systems, this study aims to address some of the challenges of providing personalized e-coaching for users with a specific condition, such as users with impairments, through the ontological user profiling. User profiling is the process of designing a structure that will capture the attributes determined from the relevant user's characteristics. The result of user profile modeling is the definition of a user model, a uniform template of the attributes that should be included for each user[22]. The task of representing user profiles in a model that integrates diverse kinds of data provided by various sources motivates the employment of ontological technologies within this study. Specifically, ontologies are recognized in supporting the flexible use and reuse of captured information also the integration of collected information.

To address the limitations of previous e-coaching systems, the system proposed in this paper solves the problem that was only partially addressed in the models previously discussed in the literature. The developed ontology is the module that will be used by an e-coaching system to support an intervention program from our domain experts [3].

This paper focuses on the modeling of user profiles to *support* specific inference within a comprehensive ontology model of the users'

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related knowledge for ontology. The remainder of the paper is organized as follows: Section 2 discusses existing related work within the area of ontological user profile modeling and personalization. Section 3 explains how the proposed ontology was developed. Section 4 focuses on the use of ontological user profile modeling for user personalization. Section 5 introduces the area of rule-based personalization, where a new personalization component is described. Section 6 discusses the system implementation, preceded by a case study presenting the potential of the ontology model and personalization component. Section 7 concludes the paper and provides a summary of future work.

2 RELATED WORKS

2.1 Personalization in e-coaching systems

The main advantage of a personalized e-coaching system is the ability to provide or offer feedback, question or advice that is tailored to the individual's characteristics in a specific situation[9]. Personalization in e-coaching systems depends on the user's profile and contextual data, coaching plan and process, and also historical user's feedback. When the available feedback or other contextual data are not available, it becomes more difficult to produce accurate coaching actions[12]. Research into personalization has been carried out for some time in the fields of artificial intelligence (AI), data retrieval and data mining[6]. The implementation of e-coaching systems resulting from these efforts utilized AI techniques such as knowledge representation. Defining and representing data or related domain knowledge is a fundamental approach to allow reasoning and to provide personalized e-coaching activities in e-coaching systems [12].

2.2 Ontology-based representation

Ontology has gained much popularity and importance in recent years for knowledge representation. The ontology-based solution has been well known over the past few years in enabling a higher level of abstraction. Ontologies have been found to perform better in user profiling when they are compared with other methods used[22]. Also, ontologies are one of the most popular approaches for representing actionable knowledge, such example can be found in physical activity domain [11, 24, 28].

2.3 User profiling technique for personalization

Personalization is usually based on a user's profile. Such profile captures the user's preferences and other characteristics that enable a system to present information that is relevant to them. Previous studies have defined or reused ontologies to represent users in health-care environments such as: monitoring users in ambient assisted living [21], providing individualized nutrition recommendation [1], as well as providing tailored coaching message to promote physical activities [27]. Finally, the work in [5] includes the user's profile and behavior to retrieve personalized food and health recommendations.

According to Schiaffino and Amandi[18], a user profile is vital information about an individual person. In the context of our system, to gather the data for user profiling, the system collects raw data from the user either explicitly by direct human intervention or implicitly by automatically monitoring the user's actions or behavior. In the profile construction phase, both types of data are combined to form information that is input to the system's personalization component. The user's profile is, therefore, a record of his or her unique characteristics such as:

- Impairment characteristics
- Motivation readiness characteristics
- Socio-demographic characteristics
- Health condition characteristics

This information is then stored as a concept profile. By applying the profile to a system or application, such as e-coaching system [9], personalized e-coaching (e.g., strategies, goals, exercise) can then be provided to the user to improve his or her health condition.

3 METHODOLOGY: ONTOLOGY ENGINEERING PROCESS

This section discusses the detailed development process of the user profile ontology. An ontology engineering methodology[25] is adopted. The choice of this methodology for developing the ontologies in our e-coaching system is based on its scenario to facilitate re-engineering of ontological and non-ontological resources to build a complete and consistent ontology. Figure 1 depicts the ontological development methodology that was carried out in a set of sequential steps. In this paper, we only focus on the first two steps which are knowledge acquisition and ontology construction.

3.1 Knowledge acquisition

In this phase, the knowledge required to build the ontology comes from several reliable resources, including domain experts' opinion, existing data tables obtained from the previous participant case studies, existing ontology repositories, relevant experts' protocol documents, and recent literature and guidelines. Initially, we determine the source of information to construct the user profile.

To determine the concepts and relationships among the terms, firstly, we conducted literature analysis through textbooks and research articles, however, the results are insufficient and incomplete to fulfill the requirements of the e-coaching system. After meeting with the domain experts, we obtained several knowledge sources(e.g., previous participant's case studies and existing data tables) that were useful to generate the concepts and relationships. Consultation meetings were arranged with our domain experts to clarify the relevant types of user's impairments, rules, and flow of the processes that need to be performed by the users. The extracted information provides an initial outline of user-related concepts, conditions, and relationships to be included in the ontology.

3.1.1 Re-engineering non-ontological resources. The re-engineering process was carried out to obtain an ontology from the gathered information. We defined our selected non-ontological resources, and then, we analyzed these resources to identify a sequence of the coaching phases(which are made up of a collection of barriers, strategies, and goals). In the case of impairments, the impairment types were identified and were classified.

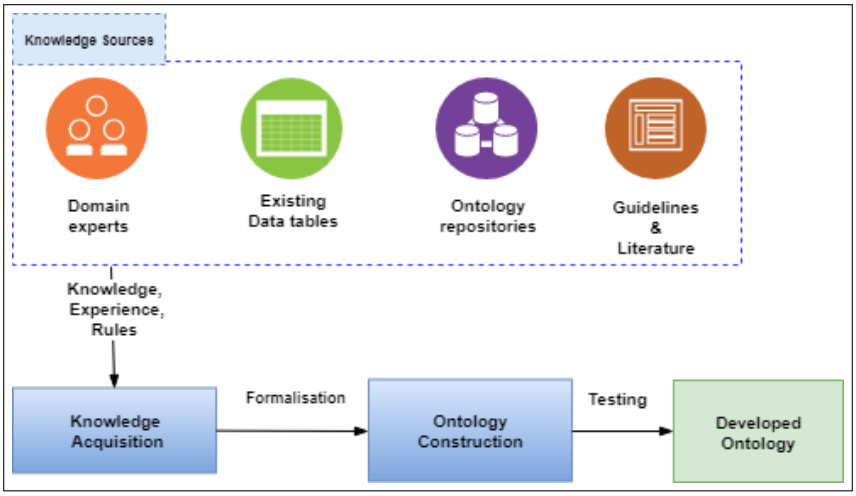

Figure 1: Methodology for ontology development

3.1.2 Reusing and re-engineering ontological resources. We had considered existing user profile ontologies and imported some parts of the following ontologies:

(1) For the impairment concept, some characteristics are imported from Accessibility ontology [17]. This ontology links the characteristics of users with disabilities, functional limitations, and impairments. We use an object property to link this ontology to the $ImpairmentProfile$ concept
(2) For the personal profile concept, the demographic information is imported from GUMO ontology[7]
(3) For exercises and lifestyle, the ontology imported some terms related to physical activity from the Semantic Mining of Activity, Social, and Health (SMASH) [4] ontology. This ontology escribes the semantic features of health-care data, specifically data related to physical activities.

None of the previous ontologies offers a complete user profile according to our e-coaching system's requirements: user's personal details, health-related conditions, impairments and method from the physical activity promotion program in [3]. Thus, to model the user profile, we organized and extended these ontologies according to our requirements.

3.2 Ontology construction

Ontology construction is the core phase, which involves the creation of an ontology framework. The next section shows the construction process of this new ontology to model the user profile.

4 ONTOLOGICAL USER PROFILE MODELLING

In knowledge-based systems, concepts are used not just as terms, but also as computable objects with logical definitions, which enable knowledge for inductive and deductive reasoning. The data captured in the user model is represented by the concepts. The main concepts of the ontology are shown in Figure **??**. This follows a top-down design approach, where "high level" or general concepts relating to the user are captured (e.g. "Impairments","PersonalProfile" etc.). The main concept, $User$, represents any user of the e-coaching system and the $UserProfile$. It links semantically to a number of key concepts and decomposes into more detailed or specialized attributes or properties. This ontology enables a dynamic profile of the user to be stored and maintained. For instance, the user's can be updated continuously as he or she achieves the targeted goals. Also the *MotivationReadiness* stages can be updated dynamically when an activity progress occurs or when a change is noted in the $ActivityProfile$. The important concepts in the user profile ontology are as follows:

(1) *ImpairmentProfile*: this concept defines the core impairments considered important for delivering the e-coaching, in the context of our system is the promotion of physical activity participation. We used numbers to identify each impairment category as follows: 1.Impairments in Sensation; 2.Impairments of Physical Structure; 3.Impairments of Physical Function; 4.Behavioral and Emotional Impairments; and 5.Cognitive Impairments. The naming system to identify each combination of impairment categories to which a user belongs consists of all impairment identifiers in numerical order. The category of impairment was identified as one of the most important determinants for the mechanism of personalization.
(2) *MotivationalReadiness*: this concept defines the individual's stage of change, which described in [15]. The concept is based on a behavior change technique(Trans-Theoretical Model) [16].
By using the information in *ImpairmentProfile* and *MotivationalReadiness* concepts, the system is able to identify the user's possible barriers, which is stored in the *Barrier* concept.
(3) *Barrier*: this concept related to difficulties or obstacles needed to overcome by the individuals to adopt or maintain the delivered e-coaching.
(4) *Goal*: this concept defines the targeted goal of the user
(5) *Value*: this concept related to the identified value that motivates a user. Individuals were required to select values that

related specifically to their situation. This information is used to determine the individual relevance of the goal that was set.

(6) *PersonalProfile*: this concept is related to the personal characteristics associated with a user profile. This is useful for categorizing or classifying individuals or for identifying particular user needs or requirements.
(7) *HealthConditionProfile*: this concept defines any existing health conditions associated with a user.
(8) *Preference*: this concept defines any existing information regarding an individual's preferences, such as physical activity preferences.
(9) *ActivityProfile*: this concept captures the related information regarding individual activity objectives, for example maintaining weekly or daily physical activities.

There is a hierarchical relationship between the top and second level classes and the object and data properties for the top-level classes. For instance, each *Goal* hasStartTime and hasFinishTime , and each "ActivityProfile" links to "PhysicalActivity" which has physicalActivityDataProperty. This enables the ontology to keep a record of the user's physical activities and the goal within which they occur, allowing the ontology to be refined.

4.1 Constructing the ontology

The next stage is to construct the ontological structure as shown in Figure **??**, linking the key concepts in the ontology. The first step is to define the classes using the names from the concepts defined previously. We include uniques identifier names and the narrative for all the classes. Finally a number of possible attributes can be listed in Table 1. We have built a schema by joining all the concepts in a unique user profile. This schema is shown in Figure 3. The user profile ontology was formally described in OWL using the Protégé editor to define these basic elements: 1) classes, 2)properties, and 3) individuals. These elements are used to describe concepts, members of a class, relationships between individuals of two classes (object properties) or to link individuals with data-type values (datatype properties), which are shown in Figure 4 and 5.

Object (Class) Properties. In this stage, we defined the object properties so that the classes can be related to each other classes.

Data Properties. To efficiently develop the ontology, we carefully defined the data properties in such a way that it could provide more information. After carefully studying from the knowledge sources described in 3.1.

4.2 Completing the ontology

To complete the process of the ontology construction, we have performed several procedures to check the consistency and to test the anomalies within the ontology. We have used the Pellet reasoner [20] that allows the reasoning with the created instances. Several instances of the $UserProfile$ class were defined, each of these instances holds specific attributes or properties concerning a particular individual. In this work, instances of the user profile class were created, where all of the concepts regarding the user are held and linked via various object and data properties.

Table 1: Examples of the Definition of Concepts in the Ontology

Concept	Attribute Name	Range
Personal Profile	hasPersonalProfile	UserProfile
	hasPersonalInfo	PersonalInformation
	hasAge	(int)
	hasName	(string)
	hasEducation	(string)
	hasTechnologyUsage	(string)
HealthCondition Profile	hasHealthConditionProfile	UserProfile
	health_relatedAttributes	(string), (double)
	isHighRisk	(boolean)
	isObese	(boolean)
WeightProfile	hasBMI	(float)
Goal	hasGoal	Goal
Barrier	hasBarrier	Barrier
	barrierAttributes	(string), (double)
Impairment Profile	hasImpairmentProfile	ImpairmentProfile
	hasImpairment	Impairment
Preference	hasPreference	Preference
ActivityProfile	hasActivityProfile	ActivityProfile
	hasActivity	PhysicalActivity
	hasPreferredActivity	PhysicalActivity

5 CONCLUSIONS

In this paper, we developed an ontological model that aims to gain relevant information (e.g. demographic, health, impairment and preference) from individuals in order to provide tailored physical activity promotion. Such an ontology provides a major step toward the development of a more intelligent e-coaching system. Our system explores ontologies mainly for user profiling purposes. The knowledge used in the ontology can be used to provide a complete picture of the user profile. For future work, as we have designed the system architecture described in [14], we aim to create a prototype for enabling the delivery of the e-coaching solution. The next stage of development includes implementation of the communication infrastructure between the architecture components.

6 ACKNOWLEDGEMENT

This research has received QUT Ethical Clearance Application Number 1700000392

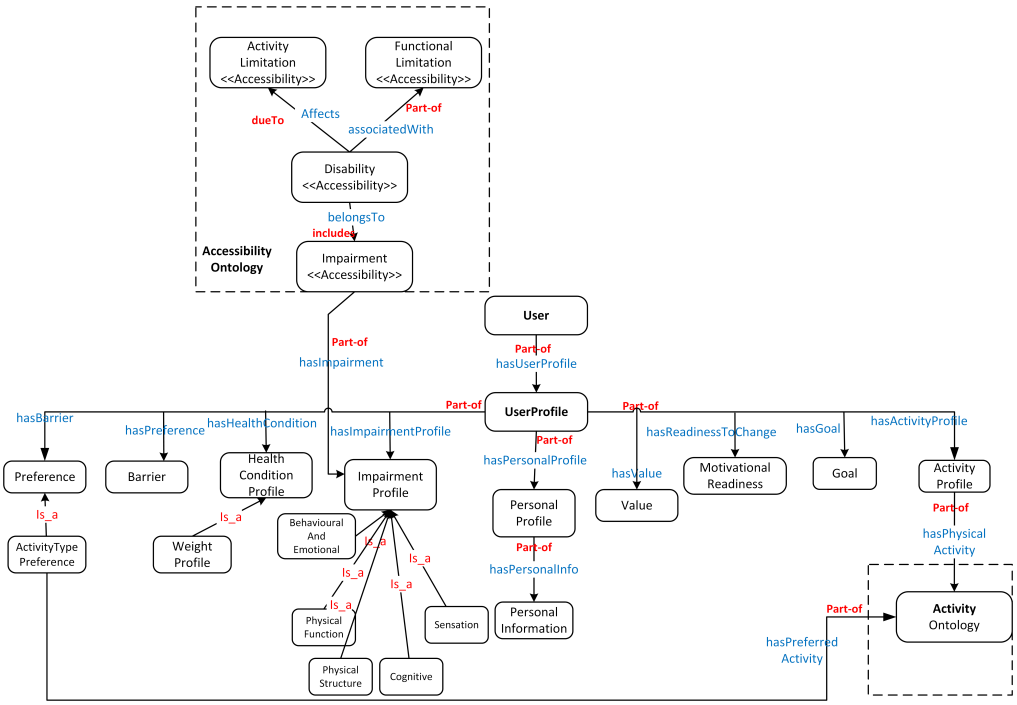

Figure 2: The Conceptual Model of the User Model

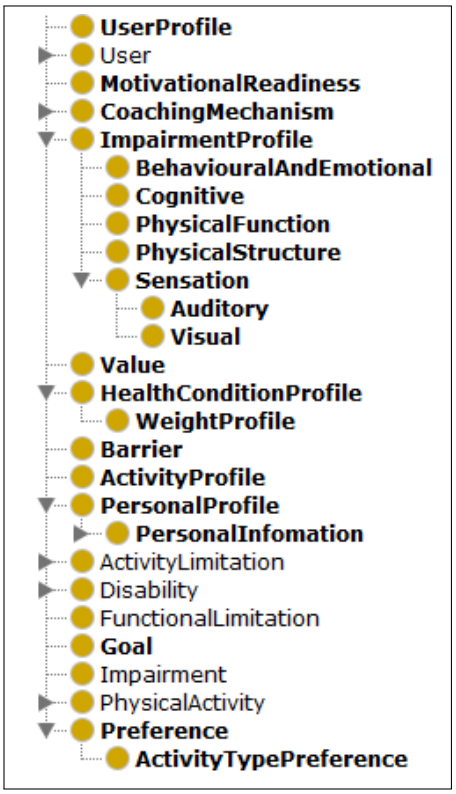

Figure 3: Ontology class hierarchy

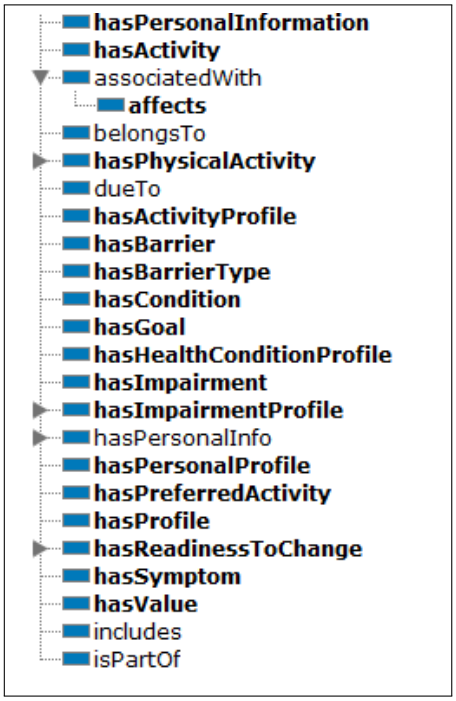

Figure 4: Object Properties

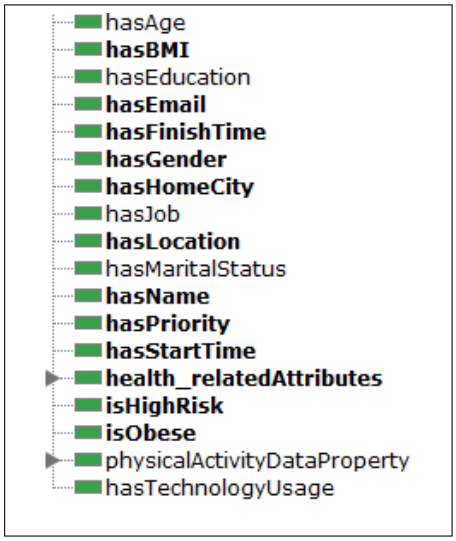

Figure 5: Data Properties

REFERENCES

[1] Ahmed Al-Nazer, Tarek Helmy, and Mohammed Al-Mulhem. 2014. User's profile ontology-based semantic framework for personalized food and nutrition recommendation. *Procedia Computer Science* 32 (2014), 101–108.

[2] Robbert Jan Beun, Willem-Paul Brinkman, Siska Fitrianie, Fiemke Griffioen-Both, Corine Horsch, Jaap Lancee, and Sandor Spruit. 2016. Improving Adherence in Automated e-Coaching. In *Persuasive Technology*. Springer, Cham, 276–287. https://doi.org/10.1007/978-3-319-31510-2_24

[3] Kelly M. Clanchy, Sean M. Tweedy, and Stewart G. Trost. 2016. Evaluation of a Physical Activity Intervention for Adults With Brain Impairment: A Controlled Clinical Trial. *Neurorehabilitation and Neural Repair* 30, 9 (Oct. 2016), 854–865. https://doi.org/10.1177/1545968316632059

[4] Dejing Dou. 2015. SMASH Ontology - Summary | NCBO BioPortal. http://bioportal.bioontology.org/ontologies/SMASH

[5] Mauro Dragoni, Tania Bailoni, Claudio Eccher, Marco Guerini, and Rosa Maimone. 2017. A Semantic-enabled Platform for Supporting Healthy Lifestyles. In *Proceedings of the Symposium on Applied Computing (SAC '17)*. ACM, New York, NY, USA, 315–322. https://doi.org/10.1145/3019612.3019835

[6] Susan Gauch, Mirco Speretta, Aravind Chandramouli, and Alessandro Micarelli. 2007. User profiles for personalized information access. In *The adaptive web*. Springer, 54–89.

[7] Dominik Heckmann, Tim Schwartz, Boris Brandherm, Michael Schmitz, and Margeritta von Wilamowitz-Moellendorff. 2005. Gumo âĂŞ The General User Model Ontology. In *User Modeling 2005*, Liliana Ardissono, Paul Brna, and Antonija Mitrovic (Eds.). Number 3538 in Lecture Notes in Computer Science. Springer Berlin Heidelberg, 428–432. https://doi.org/10.1007/11527886_58

[8] Melinda Huffman. 2007. Health coaching: a new and exciting technique to enhance patient self-management and improve outcomes. *Home Healthcare Now* 25, 4 (2007), 271–274.

[9] Bart A. Kamphorst. 2017. E-coaching systems. *Personal and Ubiquitous Computing* (May 2017), 1–8. https://doi.org/10.1007/s00779-017-1020-6

[10] Michel C. A. Klein, Adnan Manzoor, and Julia S. Mollee. 2017. Active2Gether: A Personalized m-Health Intervention to Encourage Physical Activity. *Sensors* 17, 6 (June 2017), 1436. https://doi.org/10.3390/s17061436

[11] Rosa Maimone, Marco Guerini, Mauro Dragoni, Tania Bailoni, and Claudio Eccher. 2018. PerKApp: A general purpose persuasion architecture for healthy lifestyles. *Journal of biomedical informatics* 82 (2018), 70–87.

[12] Sergio F Ochoa and Francisco J Gutierrez. 2018. Architecting E-Coaching Systems: A First Step for Dealing with Their Intrinsic Design Complexity. *Computer* 51, 3 (2018), 16–23.

[13] Stephen Palmer, Irene Tubbs, and Alison Whybrow. 2003. Health coaching to facilitate the promotion of healthy behaviour and achievement of health-related goals. *International Journal of Health Promotion and Education* 41, 3 (2003), 91–93.

[14] Puspa S. Pratiwi. 2018. Automated e-Coaching System Architecture Framework for Promoting Physical Activity. In *Proceeding of International Conference on Intelligent Autonomous System (ICoIAS 2018)*.

[15] P. S. Pratiwi and D. Tjondronegoro. 2017. Towards personalisation of physical activity e-coach using stage-matched behaviour change and motivational interviewing strategies. In *2017 IEEE Life Sciences Conference (LSC)*. 5–8. https://doi.org/10.1109/LSC.2017.8268130

[16] James O Prochaska and Carlo C DiClemente. 1992. The transtheoretical approach. *Handbook of psychotherapy integration* 300 (1992), 334.

[17] Brunil Dalila Romero-Mariño, Vanesa Espín, María José Rodríguez-Fórtiz, María Visitación Hurtado-Torres, Luis Ramos, and Hisham M Haddad. 2017. Ontology to Profile User Models with Disabilities. In *International Conference on Model and Data Engineering*. Springer, 372–385.

[18] Silvia Schiaffino and Analía Amandi. 2009. Intelligent user profiling. In *Artificial Intelligence An International Perspective*. Springer, 193–216.

[19] D. Siewiorek, A. Smailagic, and A. Dey. 2012. Architecture and Applications of Virtual Coaches. *Proc. IEEE* 100, 8 (Aug. 2012), 2472–2488. https://doi.org/10.1109/JPROC.2012.2200560

[20] Evren Sirin, Bijan Parsia, Bernardo Cuenca Grau, Aditya Kalyanpur, and Yarden Katz. 2007. Pellet: A practical owl-dl reasoner. *Web Semantics: science, services and agents on the World Wide Web* 5, 2 (2007), 51–53.

[21] Kerry-Louise Skillen, Liming Chen, Chris D. Nugent, Mark P. Donnelly, William Burns, and Ivar Solheim. 2014. Ontological user modelling and semantic rule-based reasoning for personalisation of Help-On-Demand services in pervasive environments. *Future Generation Computer Systems* 34, Supplement C (May 2014), 97–109. https://doi.org/10.1016/j.future.2013.10.027

[22] Sergey Sosnovsky and Darina Dicheva. 2010. Ontological technologies for user modelling. *International Journal of Metadata, Semantics and Ontologies* 5, 1 (2010), 32–71.

[23] Gerasimos Spanakis, Gerhard Weiss, Bastiaan Boh, Lotte Lemmens, and Anne Roefs. 2017. Machine learning techniques in eating behavior e-coaching. *Personal and Ubiquitous Computing* 21, 4 (Aug. 2017), 645–659. https://doi.org/10.1007/s00779-017-1022-4

[24] Chuan-Jun Su, Chang-Yu Chiang, and Meng-Chun Chih. 2014. Ontological knowledge engine and health screening data enabled ubiquitous personalized physical fitness (ufit). *Sensors* 14, 3 (2014), 4560–4584.

[25] Mari Carmen Suárez-Figueroa, Asunción Gómez-Pérez, and Mariano Fernández-López. 2012. The NeOn methodology for ontology engineering. In *Ontology engineering in a networked world*. Springer, 9–34.

[26] JEWC van Gemert-Pijnen, Oscar Peters, and Hans C Ossebaard. 2013. *Improving eHealth*. Eleven international publishing The Netherlands.

[27] Claudia Villalonga, Hermie Hermens, Luis Javier Herrera, Hector Pomares, Ignacio Rojas, Olga Valenzuela, Oresti Banos, et al. 2017. Ontological modeling of motivational messages for physical activity coaching. In *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare*. ACM, 355–364.

[28] Wilko Wieringa, Harm op den Akker, Valerie M. Jones, Rieks op den Akker, and Hermie J. Hermens. 2011. Ontology-Based Generation of Dynamic Feedback on Physical Activity. In *Artificial Intelligence in Medicine (Lecture Notes in Computer Science)*. Springer, Berlin, Heidelberg, 55–59.