Knowledge Management for Intelligent Fitness Planning Service in a Cloud

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Abstract. Good physical fitness generally makes the body less prone to common diseases. Doing exercise with a personal fitness plan can bring good effect to our body; otherwise, it may cause some damages to our body. This research aims to solve these problem, we develop an ontology-driven knowledge-based health care system for generating custom-designed exercise plans based on a user's profile and health status, incorporating international standard Health Level Seven International (HL7) data on physical fitness and health screening. The generated plan exposing Representational State Transfer (REST) style web services which can be accessed from any Internet-enabled device and deployed in cloud computing environments. To ensure the practicality of the generated exercise plans, encapsulated knowledge used as a basis for inference in the system is acquired from domain experts. The proposed Knowledge Management for Intelligent Fitness Planning Service in a Cloud (MIFIT)will not only improve health-related fitness through generating personalized exercise plans, but also aid users in avoiding inappropriate work outs. Also, we combine Internet Of Thing with our system so that users can easily setting fitness equipment.

Keywords: Ontology, Physical fitness, Personalized exercise plan, Health Level Seven International (HL7), Knowledge-based system

1. INTRODUCTION

Technological advancement in economics and medical knowledge has increasingly raised the public awareness of health issues for promoting longevity and quality of life. While standards of living have improved with the rise of technology, stresses and deteriorated environmental factors such as air and noise pollution lead to an increase of —sub-health‖ phenomena. As defined by the World Health Organization (WHO), sub-health is a state between health and disease when all necessary physical and chemical indexes are tested negative by medical equipment, and things seem normal, but the person experiences all kind of discomfiture and even pain. For example, a —healthy person who lacks flexibility or muscular endurance could easily be injured by lifting a heavy box, and thus would actually be considered sub-healthy. Ontology is an emerging technology which enables the advanced representation, management, and sharing of knowledge. It is also central to many applications in fields including information management, systems integration and semantic web services etc.. There are in general three major uses of ontology: (1) to assist in communication between human beings; (2) to achieve interoperability (communication) among software systems; and (3) to improve the design and the quality of software systems. With the features and results of related studies, ontology technology presents great potential to be applied in building exercises representation and the reasoning of personalized exercise plan based on users' physical fitness test results and health screening data. Through an ontology-based knowledge engine, cross-domain knowledge solicited from human experts can be visualized and applied to reasoning and modeling.

To ensure the interoperability of electronic health data (for fitness and health screening) in an ontological knowledge engine, a uniform medical information standard Health Level Seven (HL7) was adopted. As a global authority on standards for the sharing, integration, and retrieval of electronic health information, HL7 responds to the increased demand in healthcare interoperability that enhances care delivery, optimizes workflow and augments knowledge transfer. The main objective of this research is to develop an ontology driven knowledge-based system for generating specifically designed exercise plan based on: (1) the user profile; (2) the HL7-based data of user's physical fitness; and (3) the HL7-based data of user's health screening to improve physical fitness and to make the body less prone to common diseases. The generated exercise plan can be accessed ubiquitously by using any Internet-enable device through the paradigm of REST service. In order to generate a personalized exercise plan, which is pragmatic, the encapsulated knowledge used for inference in the systemis acquired from the domain professionals.

2. Related Works

2.1 Ontology and HL7 Standard

Interoperability is one of the most essential requirements for health care systems to reach the benefits promised by adopting HL7-based systems and Electronic Medical Records (EMRs). There are significant numbers of methodologies and architectures developed to address the issues of interoperability of the coalition's systems in recent years. Slavov et al. proposed an HL7-compliant data exchange software tool called Collaborative Data Network (CDN) aiming for clinical information sharing and querying. The clinical documents in CDN are modeled in compliant with HL7 v3 standard and encoded in eXtensive Markup Language (XML) format, which can be ultimately deployed in a cloud environment to support large-scale management and vast amounts of clinical data sharing.

The integration of HL7 standards and ontology technology has been widely applied in supporting system interoperability among applications in the medical domain. By assimilating HL7-compliant clinical message with ontology, Orgun and Vu developed an electronic Medical Agent System (eMAGS) to facilitate the flow of patient information across health care organizations. A simulation framework and computational test-bed was proposed by Argüello Casteleiro et al. for supporting simulations of clinical situations that boosted the integration between HL7 and ontology to achieve content layer data modeling and interoperability between online clinical cases and medical guidelines. Similar works are further elaborated in. As a core component of the proposed MIFIT, the knowledge engine was built on top of problem-oriented medical record ontology ―HL7-sample-plus-owl‖ defined by World Wide Web Consortium (W3C) as illustrated in. According to W3C, ―The goal of HL7-sample-plus-owl is to define a minimal set of terms that connect representations from well-defined healthcare information and process models with more expressive foundational ontologies through the use of the criteria outlined in the traditional problem-oriented medical record structure. To ensure ubiquitous accessibility and wide area interoperability, we designed and developed MIFIT, an HL7-compliant system driven by an ontology-based knowledge engine founding on HL7-sample-plus-owl. MIFIT is capable of processing user health screening data and personal information from any HL7-enabled medical organization and subsequently generates personalized exercise plans.

2.2 REST Style Web Services for Building Ubiquitous Web Services

Representational State Transfer (REST) is a patter n of resource operations that is introduced by Roy Fie lding as architectural style for distributed hypermedia s ystems, describing the software engineering principles a nd the interaction constraints. The REST services appr oach provides an efficient way to cope with the highly complex computing demand and intensive information provisioning in ubiquitous environments. For example, a multi-domain context-aware service platform CUBIQ (Cross UBIQuitous platform) was established in Japan using REST services. The platform enables heterogene ous devices, sensors, mobile phones, and actuators, to be integrated and universally functioned. Guinard *et al.* developed an interesting REST-based system architectu re which allows business process designers to dynamic ally query and use running instances of real-world serv ices and business applications.

3. Methodology

Domain knowledge encompasses the breadth of kn owledge within a field. Developing a knowledge engin e to generate pragmatic, personalized exercise plans re quires a prior understanding of the process of plan der ivation from the perspective of domain professionals. We collaborated with consultants at MJ Health Screeni ng Center, one of the largest health evaluation centers in Taiwan, to capture the general workflow involved i n generating a personalized exercise plan based on fitness tests.

3.1 Ontology Engineering

There is no correct way to model a domain using ontology and ontology development is necessarily an iterative process. In this sense ontological engineering furnishes various methodologies such as On-To Knowledge (OTK), METHONTOLOGY, United Process for Ontologies (UPON), and Ontology Development 101, to cite but a few for systematically constructing ontologies.

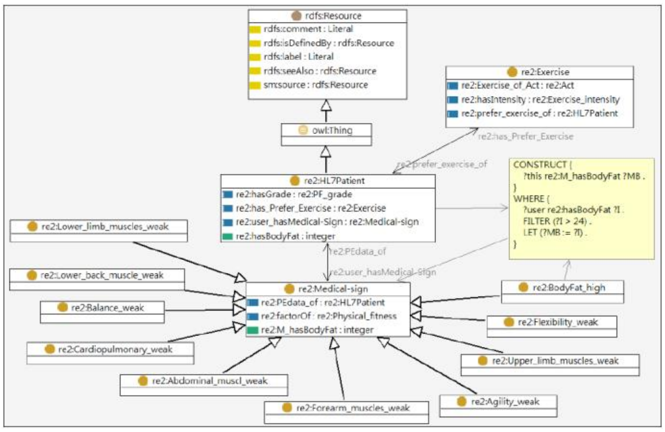


Figure 1MIFIT three ontologies-driven knowledge base.

The UFIT knowledge base is constituted by the exercise, user profile, and health screening ontologies, which defines basic terms and relations comprising the vocabulary of exercise information as well as the constraints for combining terms and relations to define extensions to vocabulary as illustrated in Figure 1. A problem-oriented medical record ontology —HL7-sample-plus-owl defined by W3C as described in Section 2.3 was reused in constructing these ontologies. The Exercise ontology developed is described below:

Exercise ontology: contains the exercise-related information acquired from domain professionals including:

• Goal of exercise (e.g., cardiopulmonary training, flexibility improvement)
• Type of exercise (e.g., jogging, swimming)
• Time of exercise (e.g., 10~15 min, 2 rounds, repeat ten times per round)
• Intensity of exercise (e.g., moderate, low, high)
• Frequency of exercise (e.g., 2~3 times/week, 3~4 times/week)
• User profile ontology: contains personal information and physical test data including
• Basic information (e.g., name, sex, age, characteristics, preference, interest)
• Personal states (e.g., exercise habit, disabilities, impairments)
• User's preferences (e.g., preferred exercise, preferred time to exercise)
• Health screening ontology: contains comprehensive health-screening information including
• Health-screening data (e.g., physiological data, triglyceride, cholesterol)
• Physical fitness test (e.g., grade 1, grade 2, grade 3, grade 4, and grade 5)

3.2 MIFIT Logical Architecture

Functionally, MIFIT is able to infer the appropriate exercise plan which defines the needed exercises through the user's profile, fitness test results, and health

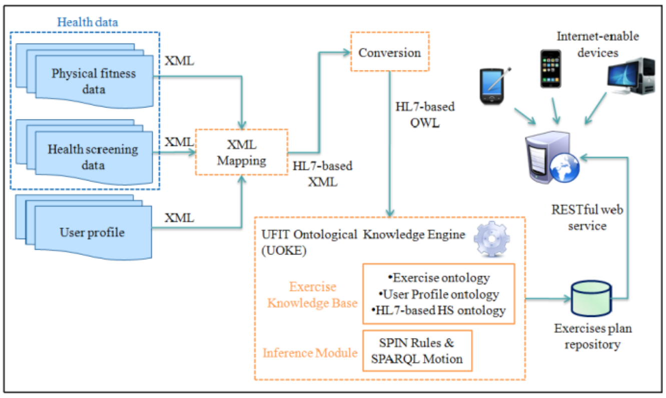


Figure 2MIFIT logical architecture

screening data. As shown in Figure 2, the process of generating exercise plan is illustrated in the logical architecture. The system is initiated with the data retrieval process:

3.3 UFIT Physical Architecture

The physical representation of UFIT interfaces and system components for the delivery and ubiquitous access of exercise plan generation services is illustrated in Figure 3

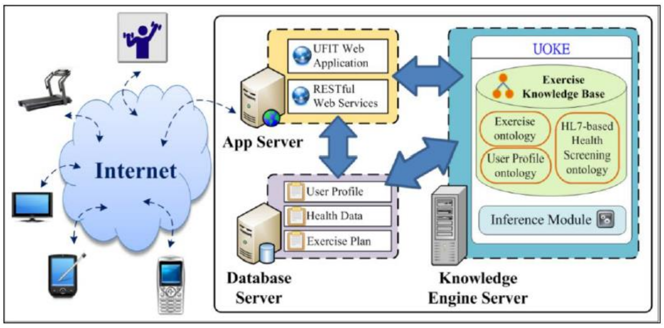


Figure 3MIFIT physical architecture

UFIT Ontological Knowledge Engine (UOKE):

3.3.1 Knowledge Engine Server

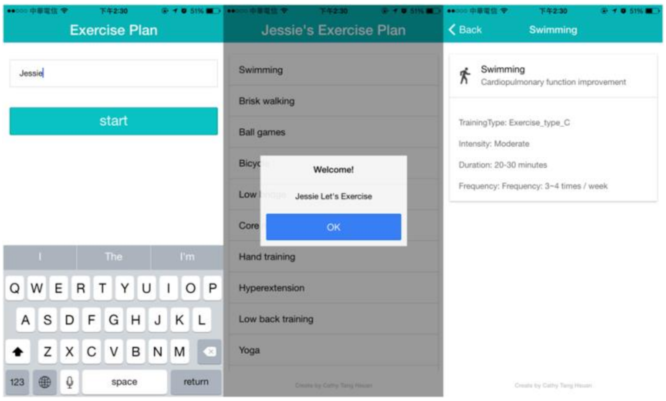
The MIFIT Ontology Knowledge Engine is deploy ed in a Knowledge Engine Server, which is compose d of the Exercise Knowledge Base and Inference Mod ule. The Exercise Knowledge Base in turn is driven b y three ontologies: (1) the exercise ontology; (2) the u ser profile ontology; and (3) the HL7-based health scre ening ontology.

The knowledge base serves as a knowledge source needed for inference personal exercise plans including knowledge acquired from professionals and the user's health status. The User Profile ontology includes the basic information (e.g., name, sex, age, characteristics, preference, interest, etc.) and the personal states (e.g., current exercise habit, disabilities, impairments, etc.) of an individual.

The data that describes personal conditions includi ng health screening data, physical fitness tests and the fitness conditions are modeled by the HL7-based Heal th Screening ontology as illustrated in Figure 2. The he alth screening data mainly records the features of body composition including body fat, triglyceride, cholestero l, and lipoprotein while the physical fitness tests cover s the resulting grades of physical tests shown in Table 2. The Exercise ontology models the characteristics of exercises including the exercise type, intensity, require d equipment, improving items etc. All exercises are cl assified into three types in accordance with training go als: Cardiopulmonary training (U2:Exercise_type_C), Re sistance training (U2:Exercise_type_R), and Stretch trai ning (U2:Exercise_type_S). The exercises associated wi th improving items such as lower body muscle strengt hening, cardiopulmonary function strengthening, flexibili ty enhancing, etc., are also modeled in Exercise ontolo gy.

The Inference Module is comprised of two compo nents: (1) SIPN rules and (2) SPARQL Motion. The k nowledge acquired from the domain professionals is m ostly encoded in SPIN rules. SPARQL Motion provide s a platform for drawing inferences on SPIN-encoded knowledge. The process for generating a personalized exercise plan comprises four stages:

1. Determine suitable exercise goals based on user 's health status indicated by the health screening data and physical fitness tests.
2. Retrieve available exercises for achieving goals.



3. Filter the inappropriate exercises based on user's

Figure 4Display at phone

profile.

3.3.2 Application Server in UFIT

The Application Server is a software framework t hat provides an environment for running and delivering UFIT applications and services. The server-side UFIT Web Application allows users to maintain data stored in the Database Server while the REST services enab le users to access their personal exercise plans ubiquit ously.

3.3.3. Database Server in UFIT

The Database Server is a repository for the User Profile, Health Data, and Exercise Plan. A user profile includes general information such as age, interests, sk ills, etc. The Health Data stores data from the user's physical fitness test and health screening. The Exercise Plan stores the user's personalized plan including: the goal, type, duration, intensity and frequency of exerci se.

4. Implementation and Usage Scenarios

MIFIT was implemented on Microsoft Windows Server2003 Standard with TopBraid™Composer - Maestro Edition (TBC-ME). Apache Tomcat 7.0 and Microsoft SQL Server™2008 Express were used for the deployment of application server and database server, respectively.

4.1 Knowledge Engine Development

Knowledge Engine comprises the Exercise Knowledge Base and Inference Module as mentioned in section 3.3.1. The Exercise Knowledge Base encapsulates the models of knowledge acquired from domain experts and users‘ health status. It is encoded in SPIN and serves as backbone for generating exercise plans through inference.The SPARQL query serves as a structural query language to retrieve inference results, the exercise plans. An example of generated exercise plan by using SPARQL query is shown in Figure 12. The TBC-ME embedded rule-based reasoner TopSPIN which supports inference with SPIN rules and SPARQL query is applied in UFIT Inference Module.

4.2 Usage Scenario and Demonstration

Jessie has an annual health assessment including a fitness test. While traveling on business, she initiates the UFIT web service using her mobile phone, as illustrated in Figure 4a. UFIT then extracts her profile and health data to generate a customized exercise plan, as shown in Figure 4b. According to her health status, the system recommends three areas of exercise: cardiopulmonary, resistance, and stretching, but advises against certain exercise types, such as treadmill walking, because Jessie‘s medical history indicates she has been suffering from peripheral neuropathy, which can affect balance, placing her at greater risk of falling. Jessie selects the cardiopulmonary training. The recommended exercises associated with the selection are then generated , as depicted in Figure 4c.

5. Conclusions and Future Work

Exercise helps people improve their health, energy and confidence. The ideal exercise program varies from person to person based on individual health conditions and medical history, but many practitioners still take a _one size fits all‘ approach to recommending exercise regimens, and many practitioners offer inconsistent recommendations based on inconsistent judgment, which can result in inappropriate exercise programs.

This paper describes the design and development of an ontology-based web service (MIFIT) to generate personalized exercise program consistently based on personal health data (physical fitness and health screening) and profile (preference). MIFIT addresses interoperability issues in health and personal data by adopting the international standard HL7 as the input format. Furthermore, MIFIT was developed and deployed using the REST architecture, allowing for ubiquitous access via any Internet-enabled device.

ACKNOWLEDGMENTS

The authors wish to thank the MJlife Health-screening Center for their kind support in providing domain knowledge and the experimental environment. Special thanks are due to ERP/MC laboratory‘s students for system implementation and evaluation.

REFERENCES

Argüello Casteleiro, M.; Des, J.; Prieto, M.J.F.; Perez, R.; Paniagua, H. Executing medical guidelines on the web: Towards next generation healthcare. Knowl. Based Syst. 2009, 22, 545–551.

Arroqui, M.; Mateos, C.; Machado, C.; Zunino, A. REST Web Services improve the efficiency of data transfer of a whole-farm simulator accessed by Android smartphones. Comput. Electron. Agric. 2012, 87, 14–18.

Batet, M.; Isern, D.; Marin, L.; Martinez, S.; Moreno, A.; Sanchez, D.; Valls, A.; Gibert, K. Knowledge-driven delivery of home care services. J. Int. Inf. Syst. 2012, 38, 95–130

Correa, M.C.; Deus, H.F.; Vasconcelos, A.T.; Hayashi, Y.; Ajani, J.A.; Patnana, S.V.; Almeida, J.S. AGUIA: Autonomous graphical user interface assembly for clinical trials semantic data services. BMC Med. Inform. Decis. Mak. 2010, 10.

Fernandez-Lopez, M.; Gomez-Perez, A.; Juristo, N. Methontology: From ontological art towards ontological engineering. In Proceedings of the Symposium on Ontological Engineering of AAAI, Stanford University, Stanford, USA, 24 - 26 March 1997; pp. 33-40.

Fielding, R.T. Architectural Styles and the Design of Network-based Software Architectures; Doctoral Dissertation, University of California: Irvine, CA, USA, 2000.

Guinard, D.; Trifa, V.; Karnouskos, S.; Spiess, P.; Savio, D. Interacting with the SOA-Based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services. IEEE Trans. Serv. Comput. 2010, 3, 223–235.

Guo, B.; Zhang, D.; Imai, M. Toward a cooperative programming framework for context-aware applications. Pers. Ubiquitous Comput. 2011, 15, 221–233

Häyrinen, K.; Saranto, K.; Nykänen, P. Definition, structure, content, use and impacts of electronic health records: A review of the research literature. Int. J. Med. Inform. 2008, 77, 291–304.

Horridge, M.; Jupp, S.; Moulton, G.; Rector, A.; Stevens, R.; Wroe, C. A Practical Guide to Building OWL Ontologies Using The Protege 4 and CO-ODE Tools Edition 1.1. The University of Manchester: Manchester, UK 2007.

Iqbal, A. An OWL-DL Ontology for the HL7 Reference Information Model. In Toward Useful Services for Elderly and People with Disabilities; Abdulrazak, B., Giroux, S., Bouchard, B., Pigot, H., Mokhtari, M., Eds.; Springer: Heidelberg, Berlin, 2011; Volume 6719, pp. 168–175.

Jula, A.; Sundararajan, E.; Othman, Z. Cloud computing service composition: A systematic literature review. Expert Syst. Appl. 2014, 41, 3809–3824.

Kivimaa, J.; Ojamaa, A.; Tyugu, E. Graded Security Expert System. In Critical Information Infrastructure Security; Setola, R., Geretshuber, S., Eds.; Springer: Heidelberg-Berlin, Germany, 2009; Volume 5508, pp. 279–286.

Laleci, G.B.; Yuksel, M.; Dogac, A. Providing Semantic Interoperability between Clinical Care and Clinical Research Domains. IEEE J. Biomed. Health Inform. 2013, 17, 356–369.

Lasierra, N.; Alesanco, A.; Guillen, S.; Garcia, J. A three stage ontology-driven solution to provide personalized care to chronic patients at home. J. Biomed. Inform. 2013, 46, 516–529.

Li, X.; Huang, Y.; Li, Y.; Yuan, Z. Establishment and evaluation of the sub-health diagnosis model based on decision tree. In Proceedings of the International Conference on Computer Application and System Modeling, Taiyuan, China, 22–24 October 2010; pp. 15–19.

Nicola, A.D.; Missikoff, M.; Navigli, R. A proposal for a unified process for ontology building: UPON. In Proceedings of the 16th International Conference on Database and Expert Systems Applications, Copenhagen, Denmark, 22–26 August 2005; Springer-Verlag: Copenhagen, Denmark, 2005; pp. 655–664.

Noy, N.F.; McGuinness, D.L. Ontology Development 101: A Guide to Creating Your First Ontology. Stanford KSL Technical Report KSL-01–05; Stanford University: Stanford, USA, 2001.

Ohashi, M. Introduction of Ubiquitous Service Platform Project CUBIQ. In Proceedings of the 10th International Symposium on Autonomous Decentralized Systems, Tokyo & Hiroshima, Japan, 23–27 March 2011; pp. 456–461.

Orgun, B.; Vu, J. HL7 ontology and mobile agents for interoperability in heterogeneous medical information systems. Comput. Biol. Med. 2006, 36, 817–836.

Pascot, D.; Bouslama, F.; Mellouli, S. Architecturing large integrated complex information systems: An application to healthcare. Knowl. Inf. Syst. 2011, 27, 115–140.

Rector, A.L.; Qamar, R.; Marley, T. Binding ontologies and coding systems to electronic health records and messages. Appl. Ontol. 2009, 4, 51–69

Slavov, V.; Rao, P.; Paturi, S.; Swami, T.K.; Barnes, M.; Rao, D.; Palvai, R. A new tool for sharing and querying of clinical documents modeled using HL7 Version 3 standard. Comput. Methods Programs Biomed. 2013, 112, 529–552.

SPIN Support in TopBraid. Available online: http://www.topquadrant.com/products/SPIN.html (accessed on 13 January 2014).

Staab, S.; Studer, R.; Schnurr, H.P.; Sure, Y. Knowledge processes and ontologies. Intell. Syst. IEEE 2001, 16, 26–34.

TopQuadrant, SPARQLMotion. Available online: http://sparqlmotion.org/ (accessed on 13 January 2014)

Vassis, D.; Belsis, P.; Skourlas, C.; Pantziou, G. Providing advanced remote medical treatment services through pervasive environments. Pers Ubiquitous Comput. 2010, 14, 563–573.

W3C. A Problem-Oriented Medical Record Ontology. Available online: http://www.w3.org/ wiki/HCLS/POMROntology#A_Problem-Oriented_Medical_Record_Ontology (accessed on 13 January 2014).

Yong, L.; Connelly, K. Realizing an Open Ubiquitous Environment in a REST Way. In Proceedings of the IEEE International Conference on Web Services, ICWS '08, Beijing, China, 23–26 September 2008; pp. 96–103.