Ontology-based Personalized Diet Plan Web Service Using HL7 Health Screening Data

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Abstract. The advancement of medical technology greatly extends people’s lifespan. As many people try to keep well and fit, healthy diet has become increasingly important today. However, deficiencies, excesses, and imbalances in a diet can produce negative impacts on health, which may even lead to diseases. The most all-too-common diseases and symptoms can often be prevented or alleviated by better diet active living. The majority of dietitians are health professionals and are trained to provide safe, evidence-based dietary advice and interventions such as limiting maximum calorie intake daily, avoiding certain types of food, etc. However, most of people who desire health conscious diet are still in uncertain situations regarding the appropriateness of their diet plan in the context of daily life. In this paper, we developed an ontological, RESTful Diet-Aid web service based on health screening data of Health Level Seven International (HL7) to provide a personalized Diet-Aid service, which can be accessed by using any Internet-enabled device. The Diet-Aid can generate a dietetic meal or filter out unsuitable food on site according to user’s health conditions based on the accessible recipe information. The development of such a Diet-Aid is expected to benefit both institutions of health screening and food suppliers.

Keywords: Health screening, Diet plan, Health Level Seven International (HL7), Knowledge-based System, Ontology

1. INTRODUCTION

Rapid economic development and advancement of medical knowledge has elevates public awareness of health issues. Meanwhile, improved living standards have also coincided with increased stress, leading to the development of the concept of “sub-health” (Li et al. 2010), a state which lies between health and sickness. A World Health Organization (WHO) survey classifies 75% of the world’s population as being “sub-healthy” while only 5% are classified as “healthy” (World Health Organization 2006). For example, a “healthy” person who’s fasting blood sugar is 6.0 (mmol/L) might be easily ruined by diabetes if without controlling blood sugar levels, and thus would actually be considered to be “sub-healthy”. Sub-health and its related factors require urgent attention in the area of modern preventive medicine.

Healthy diet habits generally lead to better the levels of physiology data acquired from health screening tests and thus improve sub-health conditions. The physiology data,
such as levels of BMI (Body Mass Index), blood pressure and blood sugar etc., serves as the most important indicators of the relative benefits of a person’s health state. The science of nutrition illustrates how and why specific dietary aspects influence health (Snae and Bruckner 2008). Healthy diet habits not only make it easier to maintain psychological health but also make the body less susceptible to common diseases.

In some cases, a “one size fits all” approach to healthy diet habits can actually be harmful to a person’s health. However, acquiring a personalized healthy diet plan from domain professionals can be time-consuming and costly. Moreover, the domain professionals may recommend inconsistent diet plans because they are pulling their information from a variety of sources and favored practices vary depending upon a range of factors including geographic location. Inconsistent plans may result in an inappropriate dietary. A knowledge-driven information system which encapsulates the knowledge of domain professional and is capable of generating consistent healthy diet plans based on users’ existing health and medical conditions may successfully address these issues.

Ontology is an emerging technology which enables the advanced representation, management, and sharing of knowledge (Jurisica, et al. 2004). Through an ontology-based knowledge engine, cross-domain knowledge solicited from human experts can be visualized and applied to reasoning and modeling. An ontology-based Knowledge Engine could offer the following advantages over a similar engine based on conventional database architecture (Kivimaa, et al. 2009):

- more efficient and flexible in capturing knowledge about concepts in the domain and relationships between these concepts;
- the ability to maintain and extend a knowledge corpus and the ability to track the effects of changing a section of the knowledge base; and
- the ability to infer broaden knowledge that might be associated with the user’s query.

Ontological knowledge engines have potential academic and industrial applications. Guo et al. (2011) presented an ontology-based programming framework, OPEN, for rapid prototyping, sharing, and personalization of context-aware applications. The prototype OPEN adopts SPARQL as the context querying language and uses Jess as inference engine to execute SWRL rules.

A knowledge engine, consisting of an ontological knowledge base and a SPIN-based (SPARQL Inferencing Notation) inference module for generating healthy diet plans, was built in OPEN. However, the authors fail to clearly address issues of data interoperability, which is of concern in that the inputs for such a system are personal health data, which could come in proprietary formats. A uniform medical information standard format is required to ensure the interoperability of electronic health screening data in an ontological knowledge engine. HL7 is a global authority on standards for the enhancement and integration of health information to promote data interoperability among hospitals at the regional level (Pascot et al. 2011), providing a set of standards for the exchange, integration, and retrieval of electronic healthcare records (Vassis et al. 2010).

1.1 SPARQL Motion and knowledge Engine

SPARQL is well established as the standard RDF query language; its name is a recursive acronym that stands for the SPARQL Protocol and RDF Query Language. It was standardized by the RDF Data Access Working Group (DAWG) of the World Wide Web Consortium (Rapoza 2006). On 15 January 2008, SPARQL became an official W3C Recommendation (Herman 2008). Comparable to SQL, SPARQL provides the SELECT keyword to extract information out of an RDF/OWL repository. SPARQL also provides the CONSTRUCT keyword to construct new triples from existing ones, making SPARQL an attractive solution for defining ontology mappings or rule bases.

SPARQL Motion™ is a visual scripting language and engine for semantic data processing (TopQuadrant 2009). It is fully compliant with W3C standard languages SPARQL, RDF, and OWL. SPARQL Motion scripts can be defined and shared as OWL models, based on a dedicated SPARQL Motion ontology and module library. Furthermore, SPARQL Motion scripts can be executed as RESTful (REpresentational State Transfer) Web Services (Fielding, R.T. 2000), an architectural style that allows access to services over the Web using only a simple URL. It leverages REST technology to extend SOA (Service-Oriented Architecture) to the web, making it possible to use the Web as an SOA platform. Using SPARQL Motion with RESTful services, we can easily expose data and content for use and reuse by current and future applications. Reasoning/inferencing may be performed using SPARQL Motion based on the SPIN-encoded knowledge base to generate knowledge-oriented results. SPIN is a standards-based way to define rules and constraints for Semantic Web data. SPIN is able to link class definitions with SPARQL queries to capture constraints and rules that formalize the expected behavior of those classes. In this research, we used SPIN to express rules in SPARQL and execute them directly on RDF data and models.

The proposed Diet-Aid adopts SPARQL Motion as the inference engine to derive knowledge required to generate

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personalized healthy diet plans and publish Diet-Aid as a RESTful Web service. With consideration for future expansion of the proposed system, TopBraid™ Composer - Maestro Edition (TBC-ME) \(^b\) was adopted as the development platform, which allows for the construction and execution of SPARQL Motion scripts for processing data chains and creating integrated web services.

In this paper, we describe the development of an ontology-driven knowledge-based system for generating personalized healthy diet plans based on 1) user profile and 2) HL7-based personal health screening data. RESTful Web services allow the resulting plan to be deployed in cloud computing environments and accessed on any Internet-enabled device. To ensure the usability and practicality of the resulting diet plans, the knowledge encapsulated in the proposed system’s knowledge engine is sourced from domain professionals.

The remainder of this paper is organized as follows. In Section 2 we discuss studies related to ontology, HL7, and ubiquitous computing. The Diet-Aid design and framework of the knowledge-based system which includes the ontology-based knowledge engine is presented in Section 3. In Section 4 we illustrate major implementation details including the system configuration and implementation of a sample scenario. Finally, in Section 5 we provide conclusions and suggestions for future research.

2. RELATED WORKS

2.1 Ontology-based Applications

Generally, an ontology is defined as a formal, explicit specification of a shared conceptualization (Gruber, T.R. 1995). An ontology describes the concepts and relationships that are important in a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary (Gruber, T.R. 1995). An ontology consists of classes, properties and instances. Classes define a concept. Instances are elements of classes and are linked to classes via properties. Properties can be used to state relationships between individuals, or between individuals and data values. The aim of an ontology is to formalize domain knowledge in a generic way and provide a common understanding of a domain, which may be used and shared by applications and groups. Ontology is also an emerging technology for knowledge representation (Smith, M.K. et al. 2004) in which it helps realize reasoning and can be used in data integration (Tang and Meersman 2011).

Ontological technology has been widely adopted in the business and scientific communities as a way to share reuse and process domain knowledge. The technology is also central to many applications in fields including information management, systems integration and semantic web services (Smirnov, A. et al. 2007). Many studies have also demonstrated that ontology is essential for the development of knowledge-oriented systems.

Huang et al. developed a medical ontology to serve as the foundation for an intelligent Chinese Medical Diagnostic System (CMDS) which acts as a human expert to diagnose a number of digestive system conditions including stomachache, vomiting, hiccups, diaphragmatitis, bellyache, diarrhea, dysentery, constipation, jaundice, tympanites, etc (Huang and Chen 2007). Bouamrane et al. (2011) presented the design and implementation of an ontological knowledge-based preoperative assessment support system, which is a generic clinical screening process, intended to identify early on in a patient journey potential risks of complications during or after surgery.

Juarez, J.M. et al. (2009) proposed an ontology-based medical knowledge base called the Causal and Temporal Knowledge Acquisition (CATEKAT2), which provides physicians with a broad spectrum of medical knowledge. Kola, J. et al. (2007) developed an ontological knowledge base to drive an Occupational Health Application (OCHWIZ) which provides suggestions as to possible causes and industries associated with a given clinical finding related to a specific occupation. Based on these suggestions, it is also capable of inferring other diseases and conditions to watch for.

Tseng, KF. (2010) proposed using semantic Web technology to build an ontology-based semantic search system for planning health-related fitness training programs in elementary schools. Coronato et al. (2009) presented a semantic location service to locate active mobile objects such as mobile devices and RFID-tagged objects in smart and intelligent environments.

Medical differential diagnosis is based on the estimation of multiple distinct parameters to determine the most probable diagnosis. Ángel et al. (2010) proposed an ontology-driven medical diagnosis system, ODDIN, which uses ontologies representing specific structured information, computation of probabilities of various factors, and logical inferences of the patient’s signs and symptoms. ODDIN may serve as a training tool for decision-making by medical personnel and students.

Alexandrou et al. (2011) described an ontological software platform SEMPATH, which can offer personalized treatment plans by using and managing health care business processes (clinical pathways). During the execution of clinical pathways, the system considers the patient’s clinical status and reaction to the treatment scheme according to the SWRL rules in reconfiguring the next

\(^b\) TopBraid Composer.
treatment steps.

Snae and Bruckner (2008) designed and proposed a counseling system, Food-oriented ontology-Driven System (FOODS), for food or meal planning in restaurant, clinic/hospital, or at home. The FOODS system equips with a knowledge engine which works to inferring appropriate foods or meals for customers based on the food ontology. The food ontology specifies the related knowledge of the meals involving gastronomy, ingredients, substances, nutrition facts, and recommended daily intake, etc. It provides a reference and base for us to construct our food ontology in Diet-Aid.

2.2 Health Level Seven (HL7)

Interoperability is a fundamental requirement for health care systems to derive the benefits promised by the adoption of HL7-based systems. Shieh (2005) proposed a data exchange model that follows the HL7 protocol in the eXtensive Markup Language (XML) format, to represent clinical information in healthcare domains. The model can also provide suggestions to hospitals for their future work on the development of Electronic Medical Records (EMR).

The Taiwan Association for Medical Informatics (2006) developed a system called HWS (HL7 electronic patient records and Web Services exchange system) to achieve health care information exchange and interoperability. HWS gives developers access to longitudinal medical records for the development of interoperable health care systems (Wu, C.H. et al. 2006).

To ensure interoperability, we developed Diet-Aid, an HL7-compliant system driven by a knowledge engine built on top of the ontology HL7-sample-plus-owl developed by the World Wide Web Consortium (W3C) (W3C 2007) (Figure 1). Diet-Aid can process inputs such as HL7-compliant user health screening data and personal information from any medical organization.

![Figure 1: Partial “HL7-sample-plus-owl” ontology](image)

2.3 Ubiquitous environment

A ubiquitous health service system must be based on the technology paradigms of mobile, pervasive and autonomic computing (Blobel 2011). A number of ubiquitous capture and access applications have been developed in the past (Yu et al. 2010).

Han et al. (2010) introduced a mobile u-health service system called Total Health Enriching-Mobile U-health Service System (THE-MUSS). THE-MUSS is a framework that aims to implement a ubiquitous health service environment with the functions, modules and facilities required by various mobile u-health services. In addition, THE-MUSS uses bio-sensors which are worn by users or embedded into cell phones to collect data remotely for analysis, with the cell phone acting as a gateway between the bio-sensors and the u-health service.

Koufi et al. (2010) presented a grid portal application, MASPortal, to provide medical advice to home-bound patients. MASPortal is a portlet-based application that provides remote and automated medical supervision via adaptive, easy-to-use interfaces and interactions. This supervision focuses on providing on-demand diagnosis and treatment advice which is derived from a collection of data provided manually by the patient. In addition, the integration of mobile and wireless devices with grid technology can provide ubiquitous and pervasive access to grid services. Oulasvirta et al. (2011) examined several sources of data on smart phone use, finding evidence for the popular conjecture that mobile devices are “habit-forming”, and results in behavior known as the “checking habit” - brief and repetitive inspections of dynamic content quickly accessed on the device. Their work reveals the importance of mobile access in the context of ubiquitous computing.

3. METHODOLOGY

3.1 Diet-Aid Logical Architectures

The logical architecture of the proposed Diet-Aid system is illustrated in Figure 2. The system is initiated with the data retrieval process:
screening center or medical institution by RFID (Radio Frequency Identification) or NFC (Near Field Communication).

II. Ontology Conversion: The HL7-compliant user profile and health-screening data are subsequently converted into OWL ontologies through tools such as TopBraid™ Composer (TBC). These converted ontologies will be used to derive personalized diet plans through reasoning.

III. Diet-Aid Ontological Knowledge Engine (DOKE): The DOKE is the main component of the Diet-Aid architecture. The engine encapsulates an ontological knowledge base consisting of the food ontology, user profile ontology, HL7-based health-screening ontology, a high-level abstraction of rules in the form of constraints, and low-level SPIN rules for inferring diet advices. SPARQL Motion makes inferences according to the knowledge base and SPIN rules to generate a personalized diet plan.

IV. RESTful Web Service: The RESTful way of Diet-Aid implementation enables smooth deployment of the service. Consequently, the Diet-Aid generates a personalized diet device, which can be accessed through any Internet-enabled device.

V. User Interface: The User Interface is the graphical interface, which allows users to access the food supplier (e.g. restaurants) recipes information in Diet-Aid service.

3.2 Diet-Aid Physical Architecture

The physical architecture of Diet-Aid illustrates the delivery and ubiquitous access of the designed functions. As shown in Figure 3, the architecture consists of three main components: Diet-Aid Ontological Knowledge Engine, Database Repository, and App. Server.

Figure 3: The physical architecture of Diet-Aid

I. Diet-Aid Ontological Knowledge Engine (DOKE)

The DOKE is the core component of Diet-Aid Service, which is comprised of Knowledge Base and Inference Module:

- Knowledge Base is driven by three ontologies: 1) the food ontology, 2) the user profile ontology, and 3) the HL7-based health screening ontology. These provide knowledge acquired from domain experts and the user’s health status to generate a personal diet plan.
  - Food Ontology
    The Food Ontology is defined according to the dietitians and the Department of Health, Executive Yuan. The relation between classes and instances are derived from the consultation with the dietitians of MJ Health Screening Center.
  - User profile ontology
    The User profile ontology is built according to the ACPP ontology mentioned in section 2, some properties are defined based on the food and health screening and some defines personal data.
  - HL7-based health screening ontology
    HL7-based health screening ontology comprises the normal test (e.g. height, weight, etc.), the examination test (e.g. blood glucose, blood fat, etc.), X-ray test, Electrocardiogram (ECG) test, and so on. The classes and properties of health screening are defined by the hierarchy of HL7 standards; these are extended from the HL7-sample-plus ontology mentioned in section 2.

- The Inference Module is comprised of two components: 1) SPIN Rule and 2) SPARQL Motion. Our SPARQL Motion scripts first load a user’s personal data from the user profile and health screening report. A series of SPARQL queries are then performed to generate a personalized diet plan. The resulting plan may be displayed on a screen, stored in the database server, or stored as a dynamic model that can be imported into other ontologies.

For example, suppose that a person has a fasting blood glucose value (i.e. AC) of 110. By executing the SPARQL query, the first rule (SPIN rule 1) would suggest that the person’s fasting blood glucose is higher than 100 while the second rule will infer that the person has a medical condition (“high-AC”). The third (SPIN rule 3) then creates the goal (reduce-blood-glucose), as shown in Figure 4. Once the goal has been determined, a personalized diet

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plan can be derived from in-depth inferencing according to the person’s health status.

<table>
<thead>
<tr>
<th>SPARQL query</th>
<th>SELECT ?User ?Goal WHERE { ?User DOKE:hasAC ?ACV. }</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIN rule 1</td>
<td>CONSTRUCT { ?User DOKE:hasHighAC ?HighAC } WHERE { ?User DOKE:hasAC ?ACV. }</td>
</tr>
</tbody>
</table>

Figure 4: The simple illustrations for the inference module

II. Data Repository:

The Data Repository stores the User Profile, Health Data, and Diet Plans. A user profile includes general information such as name, gender, age etc. The Health Data stores data from the user’s health screening. The Diet Plan stores the user’s personalized such as the goal of diet.

III. Application Server

The Application Server (App. Server) is a software framework that provides an environment for running and delivering Diet-Aid applications and services. The server-side Diet-Aid Web Application allows users to maintain data stored in the Data Repository while the RESTful Web Services enable users to access their Diet-Aid services ubiquitously.

- Diet-Aid Web Application provides a GUI (Graphical User Interface) through which users maintain their health screening data, and user profile.
- RESTful web services in Diet-Aid provide an abstraction for publishing information and provide remote access to the Data Repository. Traditional web-services are memory and processor-intensive, and are thus not appropriate for the limited memory and processing of the mobile devices. RESTful Web Services, however, are very suitable for such devices (Christensen, J.H. 2009). The Diet-Aid was designed in accordance with the REST architectural style, which offers ubiquitous access through virtually any Internet-enabled device.

4. IMPLEMENTATION

4.1 Hardware and Software Configurations

Diet-Aid was built on Microsoft Windows Server 2003 Standard Edition, with the Java™ SE Development Kit 1.6 installed. TBC-ME was used to develop the DOKE because the Eclipse-based TBC-ME is not only a visual ontology editor but also serves as a knowledge-based framework capable of integrating inferencing engines through hybrid inference-chaining. Most notably, TBC-ME can be used to develop and execute SPARQL Motion scripts including web services for processing data chains and creating integrated data services. The hardware and software configuration of the prototype system is summarized in Table 1.

Table 1: Hardware and software configuration of Diet-Aid

<table>
<thead>
<tr>
<th></th>
<th>CPU</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intel(R) Xeon(R) E5310 1.6GHz</td>
<td>2.0 GB</td>
</tr>
<tr>
<td>Database</td>
<td>Microsoft SQL Server 2008 Express Edition</td>
<td></td>
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<tr>
<td>Java Platform</td>
<td>Java SE Development Kit 1.6</td>
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<td>Application Server</td>
<td>Apache Tomcat 6.0</td>
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<td>RESTful Framework</td>
<td>Jersey 1.1.5.1</td>
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<tr>
<td>JDBC Driver</td>
<td>Java Database Connectivity 3.0</td>
<td></td>
</tr>
<tr>
<td>Knowledge Engine</td>
<td>TopBraid™ Composer - Maestro Edition</td>
<td></td>
</tr>
</tbody>
</table>

4.2 Knowledge Base Design in Diet-Aid

DOKE is the core component of Diet-Aid, which comprises the Knowledge Base and Inference Module. The Knowledge Base uses food type, user profile, and HL7-based health screening ontologies to represent explicit specifications of the diet domain and to serve as a backbone for inferencing. The classes, instances, and properties defined in the Knowledge Base are partially shown in Figure 5. Figure 6 depicts the partial classification and relations of the entities in these three ontologies, as developed in TBC-ME.

Figure 5: Classes, instances and properties of knowledge base design.
4.3 Inference Module Design

As described in section 3.2, the Inference Module is composed of SIPN rules which encapsulate the ontology-specified domain knowledge, and SPARQL Motion which performs inferencing. Each of the three ontologies has an associated set of SPIN rules. Figure 7 shows the example of SPIN rules defined for the HL7-based Health screening data ontology.

We used SPARQL Motion to create a RESTful web service called “getDietPlanData” that includes three modules: 1) ImportDiet-Aid, 2) ApplytopSPIN, and 3) ReturnSPARQLResult, as depicted in Figure 8. In the SPARQL Motion view, the ImportDiet module imports the food, user profile, and HL7-based health screening ontologies, together with D2RQ converted data as instances. The ApplytopSPIN module then applies the SPIN rules inference engine to the ontologies to construct the inferred RDF triples. The ReturnSPARQLResult module subsequently runs the SPARQL query and returns a customized exercise plan in JSON (JavaScript Object Notation) format, as illustrated in Figure 9.
4.4 Diet-Aid Services Providing Environment Design

App. Server is a software framework that handles all application operations between users and the Diet-Aid backend applications, which involve Web Application and RESTful Web Services. Diet-Aid’s RESTful web services are implemented using the Jersey framework configured on Apache Tomcat. Jersey is an open source community that is building a production quality reference implementation of JSR-311, which is an annotation-based API for implementing RESTful web services. Jersey provides an intuitive way to develop RESTful web services by providing annotations and APIs standardized in JSR 311. Figure 10 provides a screen capture of a sample personal diet plan published via the RESTful web service.

4.5 Demonstrate of implementation scenarios

Diet-Aid is a service that recommends customers the personalized meal, allows them to pick up their prefer sets, and filters out unsuitable food or calculating maximum intake calorie, carbohydrates, and fats as a recommendation. The following two sections will demonstrate the implementation scenarios from the suppliers’ and customers’ perspective.

I. Suppliers’ Perspective

SuitYou is a popular restaurant in Taiwan. To confront most of people facing health issues, SuitYou should offer more healthy food and variety kind of meals to fulfill the customers’ desires. However, this restaurant recognizes, despite of existing good business, they have not been able to meet the special health screening diet need of some specific customers. Hence, SuitYou considers cooperating with health screening centers to serve both general customers and health screening members.

One of the important aspects of Diet-Aid is to provide unified and interoperable recipes specifications from which user can select. Before submitting to the Diet-Aid, the recipe specification needs to be pre-processed to satisfy the following prerequisite conditions:

- The recipe specification should comply with the dietitians suggestions and
- The recipe specification needs to be in an ontological format such as RDF or OWL and can be accessed as a resource through a unique
Afterwards, Julie and her family have a dinner in a restaurant that cooperates with health screening center – SuitYou. She scans the membership card when enters the restaurant and logs in the Diet-Aid Service through the mobile phone as shown. Thus, her personal health data is acquired by the restaurant at this point. Then, Julie may choose her preferred dishes via mobile phone to verify with the Diet-Aid. This step may be repeated until desired or suitable dishes are selected. Thus, the service generates a fulfilling food advice judged according to her health information in the knowledge-based system. Figure 13 shows Julie’s physical condition exceeds the reference range, yet tolerable, such as fasting blood glucose at 125, BMI at 28.8 and WHR at 0.98. In addition, the Goal indicates the recommendation of blood glucose decrease and body weight loss. And the screen below displays maximum daily intakes of calorie, carbohydrate, and fat according to Julie’s personal health data.

Figure 14 shows dishes selected by Julie’s choice such as Rice, Fry Cabbage, Salad, and Watermelon. Furthermore, the maximum dish selection is five by users according to current design of the system. Figure 15 shows the result, such as calorie of every dish, total calorie, carbohydrate and fat, is depended on Julie’s choice. In this case, Julie receives the alert message on exceeding calories, carbohydrate and fat per meal. Therefore, in Advice dialog, Julie may adjust quantities or change to other suitable dishes as shown in Figure 16 and Figure 17. Moreover, Julie can accept the alert message or still stand to assert herself. Lastly, Figure 18 shows the result of order list by Julie. Thus, the total calorie, carbohydrate, and fat are recomputed immediately.

Figure 11: Supplier Page in Diet-Aid

II. Customers’ Perspective

Julie is a 76-year-old housewife. Her children care about her physical condition; therefore, they conduct a health screening for the mother at a health screening center. After the health screening, the report shows that she has high fasting blood glucose at 125 mg/dl, Body Mass Index (BMI) at 28.8 % and Waist Hip Ratio (WHR) at 0.98 as shown in Figure 12. Furthermore, the dietitians suggest a healthy diet with lower intake of calorie and sugar to decrease the blood glucose, thus to lower Julie’s blood sugar and body weight to normal. Upon leaving, the center offers Julie a RFID or NFC membership card which contains her health screening information. Nevertheless, Julie does not know how to prepare healthy food at her point of leaving the health screening center.
4.6 Evaluation

Based on above, evaluation is introduced in this section. It consists of dietitian perspective and Diet-Aid service perspective according to domain expert evaluation and Diet-Aid performance respectively.

1. The food advices by dietitians

Most of dietitians are health professionals who improve the health of individuals. Dietitians modify diets to treat medical conditions based on their skills and knowledge, and to advice the person on diet watch, as well as to educate the general public about eating healthy such as nutrition, calorie, avoiding certain types of food, etc. Figure 19, 20 and 21 shows the health screening data of the subject abided by dietitians in this case. Nevertheless, the health screening data is unstable.

2. The food advices by Diet-Aid

The Diet-Aid can generate an appropriate food advice except special cases. For general cases, the result can be consistent with dietitians’ advice because the system is set up based on their consultation. Therefore, the Diet-Aid will discover any omissions or errors when the advices differ from the dietitians. Figure 22, 23 and 24 demonstrates the health screening data according to Diet-Aid service of the same study case; the health screening data appears stable progress. In this paper, the Diet-Aid is built by ontology mentioned in the former chapters. In addition, the system can extend to special cases, such as expectant mothers, and has chance to become more useful, flexible, adaptable, and powerful.
The food recommendations may have a mistake by human factors; therefore, it would be lead to negative way. In this situation, the system kind of Diet-Aid can be assist to user, indeed. Ultimately, the Diet-Aid is a food assistance substitute labor in process not substitute for human.

5. CONCLUSION REMARKS AND FUTURE WORKS

Healthy diet habits help people improve their health, confidence and diseases prevention. This paper describes the design and development of an ontology-based web service (Diet-Aid) to generate personalized healthy diet plan consistently based on personal health screening data and profile (preference). Diet-Aid addresses interoperability issues in health and personal data by adopting the international standard HL7 as the input format. Furthermore, Diet-Aid was developed and deployed using the RESTful architecture, allowing for ubiquitous access via any Internet-enabled device.

This paper has been considered the personal health data and personal normal information to generate a personalized food advice on the spot. Nevertheless, it would be done for adding more nutrition or nutrition facts about the ingredients, such as amount of vitamins in the ingredients. Therefore, it could be enhanced by a matching process to the recommended daily intakes of nutrients. Another interesting aspect is to let the user view a diagram showing the indicator of nutrition balance to the meal chosen.

5.1 Limitations

An ontology as a knowledge back-end for an application, and it has great potential as an alternative to traditional knowledge driven application architectures especially in the health management field. However, still some limitations exist during the execution and implementation of Diet-Aid. One of the main characteristics of ontology is reusability. Nevertheless, different ontology designers or information providers may use different names for the same kinds of entities; even worse, they may use the same names for different kinds to represent the knowledge in the same field. Thus, this paper adopts one of the widest standards – HL7 and builds the HL7-based ontologies as part of central ontology.

The arrangement of ingredients to dishes, dishes to menus, menus to a dietary advice is hard. Thus, the food ontology can be based amongst other on ingredients and nutrition, even consultation with the dietitian. Therefore, the food knowledge base in the Diet-Aid may not far-flung of related knowledge, such as ingredients regarding such constraints as region and season, nutritional effects for health preservation such as the amount of vitamins.

This paper assumes that our ontologies serve as a foundation for data mark-up by the interested parties. It is because the information can be aggregated and combined easily due to the characteristics of the RDF model, and the integrated information can be understood if all information providers have used the same ontology to mark up their data.

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