A PERVASIVE NUTRITIONAL MONITORING AND ADVISE SYSTEM
NutriMe

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Abstract: It is well known, widely accepted, scientifically proved and published by major governmental and non-governmental organizations worldwide (e.g. WHO - World Health Organization), that nutritional misbehaviour in so called developed countries, is a major cause of diseases, morbidity and death. The phenomenon is mainly felt in aged populations, but a significant increase has also been detected more recently in young populations. This paper presents a proposal to tackle serious social and behavioural problems related to aging and nutrition. *NutriMe* is presented as a nutritional monitoring and advising system to help individuals to monitor and correct their behaviours. We also propose *NutriMe* as the main component for a public national observatory on nutritional profiles for public health analysis purposes.

1 INTRODUCTION

Several economical, social and cultural factors that took place in the last decades in developed countries have strongly influenced human diseases profiles. Among those factors, globalization and urban prevalent and increasing lifestyles are worth to mention. One of the reflexes turning out from those changes is related to nutritional (mis)behaviours (Lopes et al., 2006). Although other reflexes are also subject of research (e.g. smoking, pollution, etc.), we will not take them into account in our study, knowing that nutrition is referred as one of the most important factors.

The outcome of several years of research about nutritional reflexes on health/diseases, lead to a present common sense assumption that proper nutritional monitoring and advise is need, must be continuous, rigorous and customised for each individual, according to biological, medical, and life style parameters (Lopes et al., 2006).

The extent of many harmful reflexes (e.g. morbidity and mortality) caused by incorrect nutritional behaviours on health, have been estimated in several studies. World Health Organization (WHO) reports that 80% of cardiovascular disease cases, 90% of diabetes *mellitus* type 2 and 33% of all types of cancer could

have been prevented by adopting healthier lifestyles, which includes correct nutrition, regular physical activity and non-smoking (WHO, 2006). WHO also states that: "A change in dietary habits, physical activity and tobacco control, have a major impact in reducing the rates of these chronic diseases, often in a relatively short time".

Nutritional monitoring and advise is therefore important both in an individual point of view for individual behaviours correction, and in a global point of view, essential for global policy definitions and for nutritional education planning.

NutriMe, the system proposed in this paper, is a system designed to tackle the above presented issues. *NutriMe* can also be integrated with the *Smart pantry project - Diet module* (Alves et al., 2006), whose features consist of a subset of *NutriMe* features in the context of a smart house project focused on accessibility and inclusion.

In section 2 a general characterization is made of the *Smart pantry project* and explained its possible integration with the *NutriMe* system, followed by section 3 which presents the *NutriMe* system. Section 4 shows a *NutriMe* prototype and some issues related to the distributed data model are presented in section 5. Finally, conclusions and future work are referred in section 6.

2 SMART PANTRY PROJECT

Developed countries aged populations is raising several and severe problems related to home daily elder people tasks, such as physical access and handling of home stored goods, nutritional control and health care, etc. The *Smart pantry project* (Alves et al., 2006) was developed with the intention to fulfil some of those needs. Its main features are related to stock control, triggering advertises to replace depleted/missing products, create automatic customized shop lists, make products physically accessible to people with reduced mobility, suggesting menus tailed to user preferences and medical profiles (diets), all supported by a central database system (Barrias et al., 2008). Figure 1 presents a modular architecture for the *smart pantry* as proposed in (Alves et al., 2006).
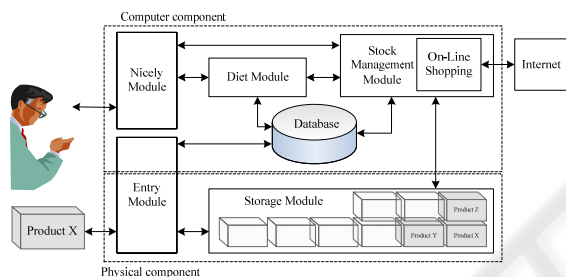

Figure 1: Modular architecture for the smart pantry Source: (Alves et al., 2006).

In this system, users enter products using the *entry module*, which automatically identifies the product, presents its features to the user and asks him for confirmation/validation. After validation, the system stores the product according to its storage conditions (temperature and humidity), size, expiry dates, etc.

Based on the storage information in the database, the *stock management module* manages the existence of stored products (e.g. expiry dates, so that they can be disposed or used), a 'shopping list' is also presented based on predicted needs, on-line shopping with supplier's systems integration (Cardoso et al., 2007), history of menus, etc.

The *storage module* consists of a robotic storage system, adapted to user needs (accessible) and to available space and conditions. It may be based on rotating shelves, suspended elements, or other systems such those employed in large-scale storage systems.

In order to produce a prototype, two basic solutions are under development: one thought to be part of traditional kitchen furniture (a numeric-

control system drawing its inspiration from a bucket chain); another will be a robotic system of the 'mini-warehouse' variety, to be installed in its own compartment – the 'pantry' (modular systems of greater capacity).

An extremely important element is the *HCI (nicely) module* (human computer interface module) that will be programmed according to user profiles and specific needs, so that the system can interact with each person according to his personal physical/psychological skills and impairments (image-based, text-based, voice based, simplified *vs.* full featured versions).

The *diet module* has a set of menus that allow the counselling of users, accounting for different criteria, such as the number of people (family size), the status of the food stock, or the way for eating adequately.

Smart pantry project *diet module* features are considered as part of *NutriMe* project as the home based monitoring and advising features. *Nutrime* intends to cope with ubiquitous nutritional monitoring also in other contexts like restaurants, canteens, bars and pubs, vending machines (food, beverage, cigars automatic selling machines), etc.

Nutrime extends the concept of nutritional monitoring to ubiquitous individual monitoring and advising system.

3 NUTRIME

NutriMe is a distributed software and distributed data based system that collects nutritional information from different sources. In addition to individual nutritional information gathering, it also links, relates data, ensures consistency and integration of syntactic and semantic data models from different sources (food suppliers – home, restaurants, vending, etc.). *NutriMe* uses that information not only for individual real-time nutritional monitoring and advising, but also for the purpose of feeding a nutritional national database (nutritional 'observatory'). The *observatory* database allows for classification, segmentation and prediction of nutritional profiles. Based on data analysis and knowledge extraction (data mining) from this database, public health policies and strategies can be better supported and deployed. Figure 2 shows the components of *NutriMe* (conceptual view).
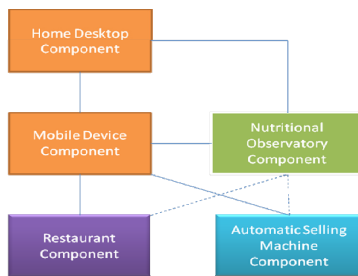
Figure 2: Components of NutriMe (conceptual view).

Each component relies on different technologies and targets different purposes and features of a global nutritional monitoring and advising system. *NutriMe* conceptual model, its individual components roles and descriptions, follow:

- *Home desktop component*, supports all the features mentioned in the *Smart pantry project – Diet module*. The major features specified are related to user profile characterisation (age, gender, physical activity profile, professional profile, medical profile, etc.), alimentary items characterisation (identification, common description, nutritional data composition, etc.), diets, healthy profiles characterisation, nutritional reports generation and nutritional advise;
- *Mobile device component*, implements a mobile version of the Home desktop component and features for interoperation and integration with all the other system components that provide (or collect) nutritional data for the individual, like the Home desktop, Restaurant, Automatic selling machines and Nutritional observatory components. It is intended to download and run mobile code made available from the other system components (e.g. in restaurants), behave like an extended GUI (graphical user interface) of those systems and interchange (collect/provide) information about individual user consumed items from those system components. The consumed items identified and/or described are to be found in the mobile device database for nutritional monitoring, processing and advise purposes. The mobile component is also able to look through consumed items description provided by the other system components, map them into the nutritional characterisation and run the respective nutritional monitoring, evaluation/ classification and advise algorithms;
- *Restaurant component*, our concept of a "smart restaurant" system component includes the

following major features: provide mobile applications/code to be downloaded into customer mobile devices allowing for customer multimedia interactive menu selection (e.g. food, drink, desert, etc.), for delivery selection (e.g. tables and location of the customers to be selected based on interactive maps), for customer identification and profile management (e.g. personal data for invoice and receipts), detailed and electronic invoice issuing (detailed info about consumed items) sent to the customer mobile device, electronic payments, etc.;

- *Automatic selling machines (vending) component*, this is a generic component representing any other system component providing and/or collecting nutritional information (e.g. beverage and food automatic selling machines). Each of these components must provide mobile code to be run on user mobile devices or implement a compliant generic communication protocol profile (to be defined) for integration with the mobile device;
- *Nutritional observatory component*, includes features of data collection from individual devices (desktop and mobile devices) and restaurant systems, data synthesis, nutritional profiles analysis based on multiple criteria (e.g. age, location/geography, profession, etc.), allowing for population risk classification and evaluation concerning nutritional behaviours and diseases prevalence analysis.

NutriMe intends to promote healthy nutritional behaviours by the means of ubiquitous nutritional monitoring in an individual and population basis (reporting individual and population nutritional warnings). In addition, it is intended to provide detailed individual nutritional advising (suggesting detailed meals according to nutritional principles and user preferences), global behaviour synthesis, risk evaluation and classification using data mining techniques.

Figure 3 shows UML (Unified Modeling Language) Use Cases specification for *NutriMe*.

It shows the system actors, features, their interactions and relationships (Fowler, 2003).
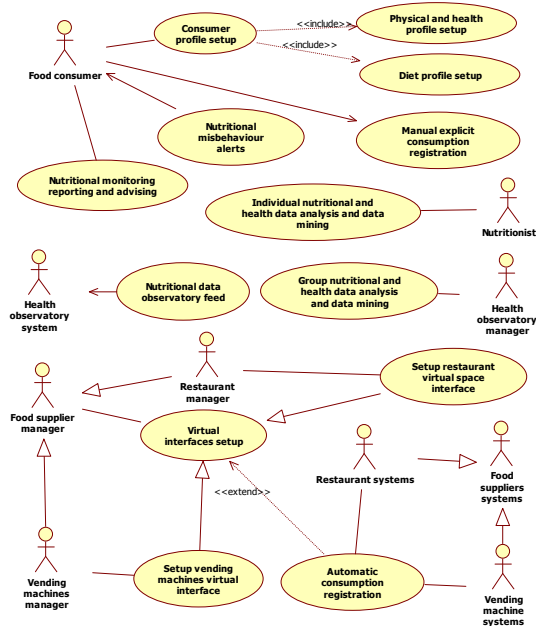
Figure 3: *NutriMe* Use-Cases Diagram.

Use Case "**Consumer profile setup**" allows the user to provide his personal data (e.g. gender, age, height, weight) to the system, defining nutritional profiles, diets and preferences (e.g. vegetarian, athlete, diabetic, etc).

Use Cases "**Nutritional misbehaviour alerts"** and **"Nutritional monitoring reporting and advising**" allows for automatic warnings from *NutriMe* towards the user, allows the user to access statistics about his behaviour and provides nutritional advising. In addition, *NutriMe* provides extra nutritional expertise and tools for knowledge extraction (clustering, classification, prediction) from monitoring data for nutrition professionals ("**Nutritionist**") decision support in "**Individual nutritional and health data analysis and data mining**" Use Case.

An observatory component of *NutriMe* is also feed by nutritional monitoring data (Use Case "**Nutritional data observatory feed"**) for "**Group nutritional and health data analysis and data mining**" purposes.

"**Virtual interfaces setup**" Use Case supports user interface, data and functional integration features between *NutriMe* and "**Food supplier systems**". For instance, it is possible for "**Food consumers**" to issue meal orders from *NutriMe* that are transmitted electronically and processed by "**Restaurant systems**". When "**Food consumers**" interact with "**Food supplier systems**" through

NutriMe "**Automatic consumption registration**" is possible. "**Automatic consumption registration**" is the preferred way of nutritional data gathering in NutriMe, but "**Manual explicit consumption registration**" by "**Food consumers**" are also available in *NutriMe*.

NutriMe simplified data model is presented in an *Entity-Relationship* diagram in Figure 4. The conceptual data model will be deployed as a distributed relational database system as detailed in section 5. As a distributed software and distributed data based system that collects nutritional information from different sources and heterogeneous technologies, concerns of consistency, correctness, integration of syntactic and semantic data models are to be considered.
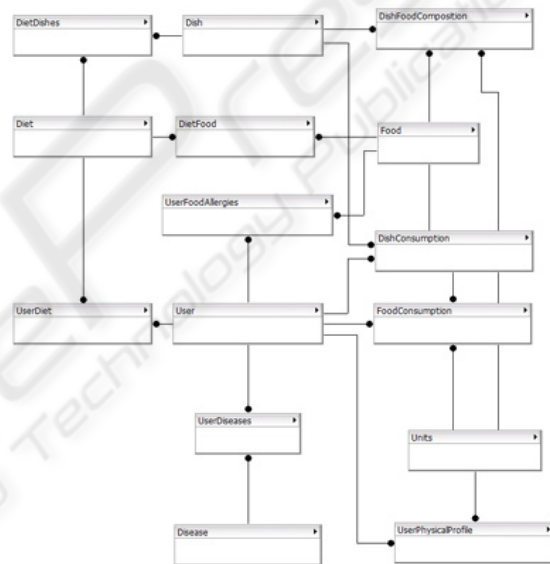

Figure 4: *NutriMe* Entities-Relationships Diagram.

An innovative implementation of *NutriMe* involving flexible and adaptive information systems integration based on desktop and mobile devices is presented in section 4.

4 PROTOTYPE

Inclusion and accessibility have been major concerns during all development life cycle of *NutriMe*. Software design and technology selection were essential to construct a solution that promotes device and software mobility, usability, high availability and continuous monitoring.

Mobile technologies such mobile phones/PDAs proved recently to ease cumbersome daily task.

Recent devices reached significant processing storage and communication capabilities, allowing increasing features and new applications. The massive adoption of this kind of devices is considered today one of the greatest success of information and communications technologies market acceptance (Paes, 2006).

The above mentioned technical factors, growing market acceptance, easy of use and ubiquity of this kind of mobile technologies, lead us to select this computing and communication technologies as the basic support for the main *NutriMe* component.

Figure 5 shows the technological solution proposed for *NutriMe* system main components, including physical/logical elements, interoperation and interactions.
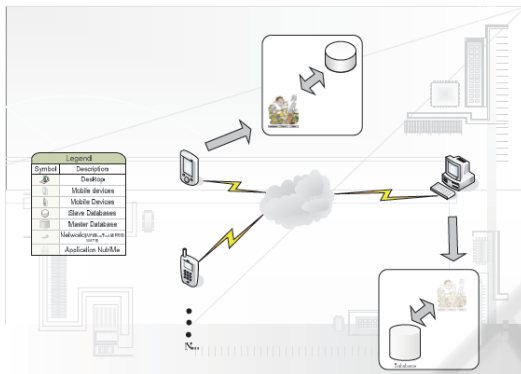

Figure 5: Technical scenario for *NutriMe* mobile component prototype.

NutriMe software (mobile and desktop) components are hosted in PC like and mobile devices (e.g. mobile phones/PDAs).

NutriMe desktop and mobile versions have been developed with Microsoft .NET 2005 Framework and Microsoft .NET Compact Framework respectively. Microsoft SQL Server 2005 and Microsoft SQL Server 2005 Compact were de DBMS (database management systems) adopted for desktop and mobile support respectively. Data replication, integrity and synchronisation are supported by both mentioned DBMS (master-slave data replication and synchronisation) which is the most common strategy adopted for similar scenarios. This strategy shows optimal trade-offs concerning quality of service (availability, punctuality, etc.) and resources consumption/usage (storage, processing and communication) within strongly connected, weakly connected and connectionless situations. Support of multiple communications technologies (GPRS, UMTS, Wi-Fi, Bluetooth), actually quite common in mobile devices, enforces applications

robustness allowing not only for horizontal but also vertical handoffs.

Next we present some prototype features and graphical user interface of *NutriMe*. User personal profile form is presented in Figure 6 (left picture) for user characterisation features of *Definition of Personal and Nutritional Profiles* Use Case. And interactive consumption registration form is also presented in Figure 6 (right picture) for *Consumption Monitoring* Use Case features.

Figure 6: *NutriMe* personal profile form and Interactive consumption registration form.

NutriMe user interface also provides friendly graphical classifications of nutritional and health ratios, such as the BMI - body mass index (Figure 6), which are subject of time evolution graphical or text based presentation and analysis.

Supporting distributed relational database technologies and strategies for *NutriMe* desktop and mobile prototypes are presented in section 5.

5 DISTRIBUTED DATA MODEL

Available commercial DBMS (e.g. Microsoft SQL Server) allow for flexible data management, enhancing application robustness, high availability and performance, being especially important in distributed systems involving mobile devices with non continuous communication connectivity. Replication strategies are usually adopted (and very effective) to overcome periods of non connectivity. However, data replication needs specific mechanisms for integrity enforcement among the copies spread throughout the several components of a distributed system (e.g. mobile and desktop equipment). While subject to isolated processing during non connectivity periods, data replicas in different processing devices can evolve to divergent, eventually inconsistent states. Automatic

mechanisms must be activated to rollback or roll-forward the replicas to get the overall distributed system back to a consistent state. The mechanisms adopted in our system for this purpose are based in the two-level master-slave transaction model (Liu et al., 1999).

One level is ruled by desktop workstations, the second level is ruled by the mobile devices (one or more devices). Data convergence actions take place when a communication channel is available between desktop equipment (master replicas) and mobile devices (slave replicas).

First, the master (re)executes all transactions made available by the slave, corresponding to all the actions performed by the slave during non connectivity periods. Second, the master notifies the slave the successful reconciliation transactions to be committed. Inconsistent transactions are tracked back until its root (causal graph node), and undone until the overall distributed system gets into a consistent status.

The presented two-level master-slave replication strategy seemed to us a suitable solution for the *NutriMe* system. It revealed optimised trade-offs according to quality of service and resource usage, in scenarios similar to ours.

6 CONCLUSIONS

This paper presents a software based system – *NutriMe*, which addresses ubiquitous nutritional monitoring and advising supported by several cooperating software components distributed through desktop and mobile devices, databases and applications. The system intends to introduce increasing computational and communication pervasive features, assisting in simple daily tasks with low or non intrusive reflexes (low or no perception or interaction required from users). Because aged populations are common in developed countries, and they have usually special needs, concerns of accessibility and usability have been of major importance in the design and implementation of *NutriMe* prototype. Individual and public interest (e.g. health, economic) of this kind of systems are worth to mention. They constituted our first interest and justified further work and research on this topic. Future work milestones include information gathering and processing in public spaces context, multimodal interfaces for impaired people, introduction of data mining techniques for customised individual user advise, extraction and

analysis of general nutritional tendencies and patterns.

REFERENCES

Lopes C., Oliveira A., Santos A., Ramos E., Severo M., 2006. *Consumo alimentar no Porto*. Porto: Serviço de higiene e Epidemiologia - Faculdade de Medicina do Porto.

WHO, World Health Organization. 2003. *Global strategy on diet, physical activity and health*. Available: URL:http://www.who.int/hpr/NPH/docs/gs_global_str ategy_general.pdf

Alves J., Cunha A., Trigueiros P., Barroso J., Cruz J., 2006. Sistema de gestão inteligente de uma despensa. In DSAI 2006, *Proceedings of Conference Software Development for Enhancing Accessibility and Fighting Info-exclusion*, Vila Real.

Barrias A., Cunha F., Varajão, J., Cunha A., 2008. Smart Pantry: specification of a management system using UML. In IADIS e-Society 2008, *Proceedings of IADIS International Conference e-Society 2008*, Algarve.

Fowler K., 2003. *UML distilled: a brief guide to the standard Object Modeling Language*, Addison-Wesley. 3ⁿᵈ edition.

Liu P., Ammann P., Jajodia S., 1999. Incorporating Transaction Semantics to Reduce Reprocessing Overhead in Replicated Mobile Data Applications. In ICDCS' 99, *Proceedings 19th IEEE International Conference Distributed Computing Systems*, Austin.

Cardoso J., Jaulino R., Varajão J., Fernandes V., Cunha A., 2007. Smart pantry: integration models with electronic commerce solutions, In DSAI 2007, *Proceedings of Conference Software Development for Enhancing Accessibility and Fighting Info-exclusion*, Vila Real.

Paes C., Moreira F., 2006. Aprendizagem com Dispositivos Móveis: Aspectos Técnicos e Pedagógicos a Serem Considerados Num Sistema de Educação.URL:http://grace.tech-x-pert.org/blogs/ files/2007/06/aprendizagem-com-dispositivos-moveis-na-aspectos-tecnicos-e-pedagogicos-a-serem-considerados.pdf