Making Environments Work for People
A Novel Approach towards Personal Lifestyle Management Informatics

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Abstract: This paper introduces a new paradigm for personalized systems used by the citizen for self-management of health and disease: using smart technologies to exploit the health potential of surrounding environments and to support the citizen in decisions related to a healthy lifestyle. This approach proposes meshing the citizen's specific needs for healthier behaviours with what is available to meet these needs in the surrounding environment. Rather than focusing on health monitoring alone, the aim should be to create a healthy digital envelope – a Healthy Place – around the citizen as they move through their everyday lives. The implementation of this approach needs to integrate existing systems for health assessment and environmental predictions; collect personal private data from mobile personal sensors and public data on health content of the environment; design dynamic testable models of behaviour change, that situate the individual within their environment; develop advanced analytics for context understanding and situational awareness that will couple the current goals of the person with what his or her environment can offer; and create personalized decision support services for behaviour change that exploit the current match between a person's needs and the opportunities offered by his or her environment.

1 INTRODUCTION

Information and communication technologies have conventionally been used to support disease management. A second generation of interventions addresses personal patient informatics, building the 'quantified self' to increase self-knowledge and autonomy via (large scale) personal data collection. The current trend is for personal devices and applications whose primary purpose is less to enlighten users with information than to urge them to change (Singer, 2015). However, broadcasting generic health messages (e.g. 'do this, don't do that') has relatively modest effects unless the context/environment makes the advocated changes very easy to carry out. Technology today cannot significantly alter physical environments in this respect, but it can alter something equally or even more important: the perceived environment.

In this paper, we propose an innovative approach of meshing the citizen's specific needs and goals for healthier behaviours with what is available to meet these needs in the surrounding environment. Rather than focusing on health monitoring alone or individual medical and behaviour change plans, the proposed approach aims to create a healthy digital envelope – a *Healthy Place* – around the citizens as they move through their everyday lives.

2 BACKGROUND

Lifestyle-related diseases are defined as non-communicable diseases and are caused by non-physiological lifestyle factors such as unhealthy diet, physical inactivity, tobacco use, excessive use of alcohol and psychosocial factors e.g. chronic stress and depression, are leading causes of death globally.

Chronic non-communicable diseases such as cardiovascular disease, cancer, diabetes and chronic respiratory disease, were responsible for 36 million deaths (67% of all deaths) in a single year (WHO, 2010). All these diseases are profoundly impacted by lifestyle options including dietary intake, exercise, stress, sleep, and use of alcohol.

Lifestyle changes in these patients can prevent the progress of the disease more successfully than

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any drug treatment (Spruijt-Metz, 2014; Wilson, 2014; Williamson, 2005; Li, 2014)

During the last decade, different forms of health care delivery have also been considered, based on the specific needs of patients with chronic diseases, such as patient empowerment. Environmental information as provided by smart cities infrastructure has been proposed to augment personal health applications and help citizens choose wisely their whereabouts in the urban environment (Solanas, 2014). Furthermore, the WHO, among others, has promoted the idea of preventing disease through healthy environments (Pruss-Ustun, 2006). To ensure sustainable healthy behavioural change, we must foster and promote environments that can support people in healthier lifestyle habits.

As it is difficult to radically change the environments of developed societies, we propose to change how the environment is perceived. This will be achieved by highlighting, on an individual basis, those aspects of the environment that are most conducive to encouraging and maintaining personalized healthy behaviours. Thus, the aim is to 'change' the place around the citizen into a 'perceived' *Healthy Place*. For the rest of this document, therefore, the term *Healthy Place* is used to refer to a place whose health-related aspects have been highlighted by the proposed technological framework.

3 HEALTHY PLACES CONCEPT

For any place of everyday life to turn into a perceived *Healthy Place*, its objects and concepts must be semantically described and linked to healthy habits and values, thus creating an augmented environment for individuals to manage health, lifestyle and disease. To be relevant, this needs to relate to the individual's every day, real world context and be coupled to the personal lifestyle and the medical/behavioural goals of the individual in question.

There are three different types of data that pertain to this approach: private personal data, public data on the ambient surroundings, and health related scientific evidence including predictive models and risk assessment (Figure 1).

Private, individual-level data includes: (a) personal information on health issues, e.g. demographics, allergies, risk factors, etc. as available from a personal health record; (b) real-time information on physical activity, location, and dietary choices; (c) lifestyle related information from the person's social media presence, including attitudes, intention and relations to the community; and (d) via analysis of the above, information on the motivational and emotional state of the person.

Public data includes data on healthy aspects of resources and activities of a place, incorporating commerce, retail, leisure, workplace and community aspects, or the ambient environment. Aggregating public data on life contexts can be driven by stakeholders in commerce, retail, leisure, workplace, community who will publish key data; it can also use participatory sensing approaches.

Major lifestyle related contexts include:

- Food: the ingredients and calorific content of food items are an obvious and important source of data when considering one's health. This data can be used in relation to: managing weight, ensuring an appropriate balance of nutrients is consumed and coping with food allergies. Additional information includes meal preparation processes, e.g. the type of fat used for frying, whether menu items have been in the proximity of nuts and other common allergens.
- Recreational activities: rich description of activities in terms of their work load, difficulty, special requirements, indications and contra-indications for the healthy person at different ages and capacities and when suffering from different health conditions and disease.
- Public Transport: with the emergence of 'Smart Cities' and public Open Data there is a growing tendency for data concerned with transport routes, stop and station locations, timetables and vehicle locations to be publicly available. This data can be used to help with maintaining a certain level of exercise and energy consumption.
- Ambient environment: temperature, meteorological conditions, noise level, air pollution, airborne allergens, etc. pollen counts, as well as meteorological conditions can affect health.

Ground medical evidence and health prediction models can serve as the basis on which the current environment is analysed for the opportunities it offers and threats it presents for the individual. The goal is to dynamically highlight the most suitable attribute of each environment for the individual and deter from any threats this environment may hold, based on the needs of each person. Thus, the same environment is presented differently according to the health condition and requirements of each individual.

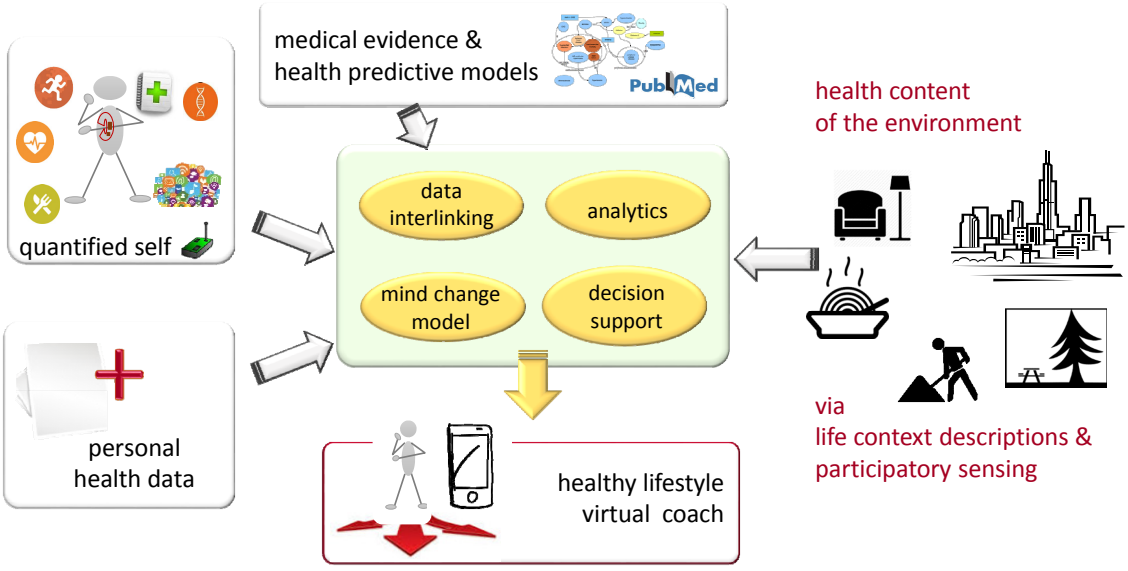

Figure 1: Data aggregation to realize the concept of a *Healthy Place*.

The coupling of public and personal data projected against a behaviour and behaviour change model to create personalized recommendation services for the citizen via a personal application. This can virtually coach individuals by supporting: (a) advanced behaviour and environment awareness; (b) self-monitoring, goal setting, and action planning; and (c) motivational and sustained behaviour change. Thus, individuals can explore personal motives, competences, life goals, preferences, social connections, and other internally-driven motivational elements around physical activity, healthy eating and healthy behaviours in general. These can be coupled with opportunities offered by the current environment. Social intelligence tools can also be used to tap into participants' sense of volition and ownership (as opposed to merely external pressure), confidence and competence (as opposed to self-perceptions of unpreparedness and even failure), and positive social support for their activities and goals.

4 OPEN RESEARCH ISSUES

The proposed concept of combining health related content with personal information to create an optimum perceived *Healthy Place* for each individual can be approached by a modular architecture as shown in Figure 2.

Starting from top to bottom, data and knowledge acquisition components acquire personal and public data. Personal data is nowadays readily available via a variety of commercially available wearable and other personal sensors and systems (e.g. personal health records). However, describing the health content of the environment may prove challenging. Participatory sensing can be employed to exploit the crowds and their mobile devices to harvest and enrich the information about the environment and living spaces (e.g. the noise level and the temperature of a place, photos of food items for optical nutritional recognition, etc.).

Information a person creates on social networks may prove to be a significant determinant of behaviour: We are all individuals who are interconnected with other individuals by personal, social, economic and workplace relationships. These connections facilitate communication, can motivate us to different behaviours, and have the potential to support shifts toward healthier lifestyles. Further research is expected to adapt and develop the necessary natural language processing, information retrieval and machine learning methods, combining data mining with semantic technologies and expertise in social media sentiment analysis.

Data enriching and interlinking is of outmost importance to bring up rich data relationships that would help couple personal health requirements with the opportunities in the environment. Thus, graph data repositories (Angles, 2012) are chosen to establish the middle layers of the proposed architecture: a public one for the health context of living spaces and a private for the personal

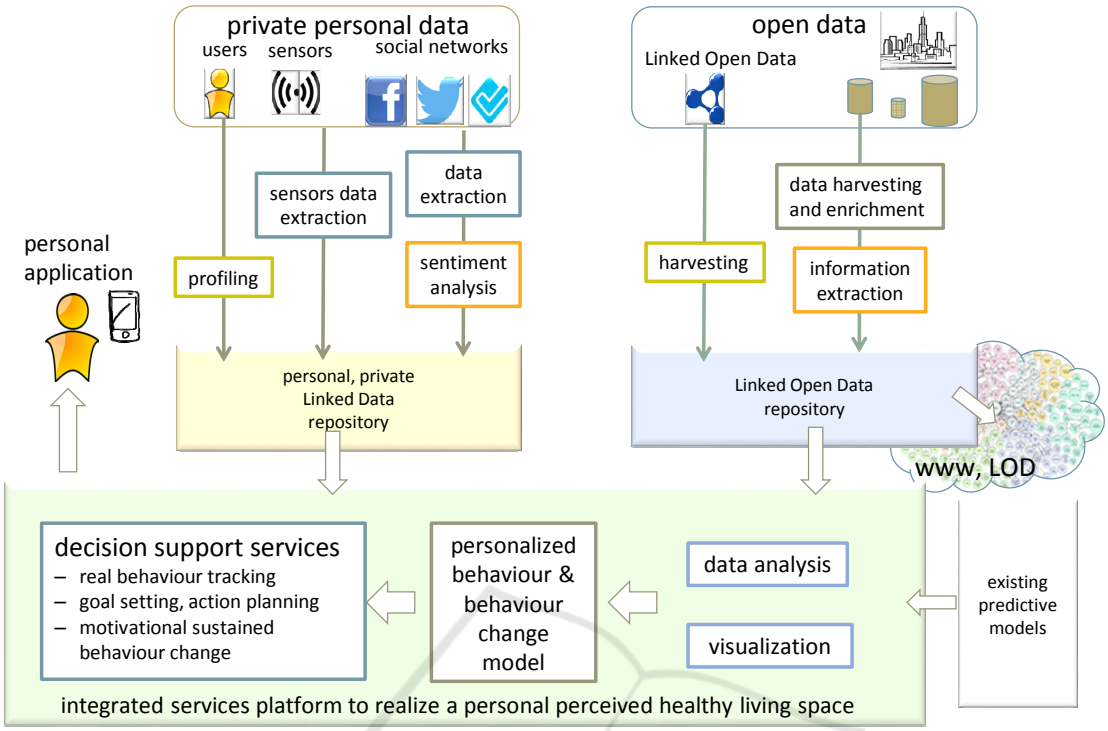

Figure 2: Overview of an abstract framework to realize personal perceived *Healthy Places*.

information. Although a lot of work has been put on releasing semantically rich Open Data, contemporary solutions often fall short of fully exploiting the Semantic Web's potential (d'Aquin, 2008). This shortcoming owes mainly to a) the shortage of adequate knowledge acquisition mechanisms, b) the lack of an environment-based, life and health related semantically integrated approach and c) the slow progress concerning the linkage of user data with the Web of Data.

Despite the proliferation of semantic web data, most published data remains semantically poor (e.g. XHTML, XML, CSV files). To leverage this wealth, research should focus on developing solutions that enable knowledge acquisition, which can be accommodated using different approaches, such as data and information extraction, and sentiment analysis. Applications that are based on traditional database modelling principles suffer from difficulty in capturing evolution of the data model, high software maintenance cost and low reusability. The semantic web achieves the translation of data across boundaries that separate different domains and overcomes these limitations (Feigenbaum, 2007). Further research is required to define and analyse the model and corresponding ontology/schema to describe health context of living spaces. This entails detailed examination and exploitation of existing health and life vocabularies and development of the appropriate Linked Services and service information (Pedrinaci, 2010).

The emergence of social web has led to the generation of user interaction and preferences traces that are often distributed, fragmented and detached (Rowe, 2009). This limitation not only complicates efforts to gather relevant user information, but also weakens the ties between personal data and the web of data. However, it fails to safeguard privacy, given the potential for a determined data-gatherer to integrate diverse data sources to form a detailed picture of an individual's actions and preferences. Concerning the linkage between personal data and the web of data further research is required to integrate personal data and web of data through a single services interface, while ensuring the highest level of privacy protection for individuals.

Support for analysis and visualization of large data sets can in principle be done by aggregation performed in either data space (data reduction) or in visual space (visual aggregation). Scalability is a key challenge in visual analytics as it determines the ability to process large datasets by means of computational overhead as well as appropriate rendering techniques. Often, the huge amount of

data that must be visualized exceeds the limited number of pixels on a display by several orders of magnitude. Currently existing techniques typically focus on a single given data type, e.g., time series or text data, so further research is required to address multiple data perspectives simultaneously.

The wealth of available personal health devices and applications, should be amended by novel applications tracking real-time personalized lifestyle to deduce the person's current real behaviour and how much this deviates from what is a healthy behaviour for this person (especially as specified by the individual in terms of his or her personal behavioural goals) and to determine mind changing actions (i.e., behaviour change through cognitive and emotional determinants). Novel tools are also required to support individuals to engage with self-monitoring, goal setting, personal projects and coping plans. New motivational and sustained behaviour change decision support applications should be devised to allow individuals to explore personal motives, competences, life goals, preferences, social connections, and other internally-driven motivational elements around physical activity, healthy eating and healthy behaviours in general.

A major enabling factor for realizing the personal healthy space via messing public and private health related data lies in the challenge to preserve privacy (Vayena, 2015). Although healthcare data are customarily anonymised to ensure a certain level anonymity (Gkoulalas-Divanis, 2014), they remain susceptible to threats caused by data linkage (e.g., with publicly available data sources) or by background knowledge. Thus, effective measures for preserving privacy must be developed (Viceconti, 2015). Also, patient consent (and its revocation) is recognized as a major limitation in broadly re-using available healthcare datasets for novel big data analytics (Barash, 2015). Additionally, the recent agreement on Commission's EU Data Protection Reform (EU Regulation 2016/679) recognizes that practices have to respect the citizens' rights to (1) easily access their own data, (2) transfer data among providers; (3) have their data deleted when no longer needed; (4) know when their own data have been hacked. Thus, new research is required to extend anonymization algorithms to work on a distributed setting, where multiple parties hold different parts of the data that cannot or are not willing to share in raw form. develop and validate computationally efficient algorithms for detecting complex events in healthcare data streams. This research should also be complemented by novel privacy preserving consent management mechanisms and cryptography enabled techniques for anonymous and unlikable feedback and reward mechanisms to return useful service output to the citizen (e.g. a health prediction or personal health status) or reward the citizen for contributing personal data.

5 DISCUSSION

In a radical departure from traditional eHealth, this paper introduces a new paradigm for personalized systems used by the citizen for self-management of health and disease: smart technologies based on existing predictive systems are used to exploit the health potential of the surrounding environment and support the citizen in his/her decisions related to a healthy lifestyle. To achieve this, novel research should address the following:

- integrate existing predictive systems from different domains, namely (a) health risk assessment models, calculating risks based on current health condition; (b) health predictive systems based on environmental factors; (c) behavioural models; and (d) predictive models of environmental parameters, e.g. weather conditions, air pollution and noise levels;
- collect personal data from mobile personal sensors but also collect data on health content of the environment via citizen participatory sensing;
- design dynamic testable models of behaviour change, that situate the individual within their environment and take full account of cognitive, social and emotional aspects;
- develop technology that allows the semantic description of health-related aspects of an environment as well as of health-related aspects of a person's behaviour;
- perform advanced analytics for context understanding and situational awareness that will couple the current goals of the person with what the current environment can offer; and
- deploy personalized recommendation services for behaviour change that, based on personalized predictions, exploit the current match between a person's needs and the opportunities offered by his or her environment.

The goal is to: (a) help citizens manage actively health and eventually adopt and maintain a healthy behaviour, and thus prevent lifestyle related diseases; and (b) make stakeholders in food, commerce, retail, leisure, workplace and community level aware of the healthy (or non-healthy) aspects of the goods, opportunities and premises they offer

to the public and provide them with technology to promote what is healthier for each citizen.

Health cannot be successfully promoted and sustained by health care systems alone – these are naturally focussed on treatment much more than prevention. At the same time, changing environments with health-related goals in mind is extremely difficult – it requires political will and sometimes costly investments; health is a goal that needs to be balanced alongside other priorities, such as prosperity or efficiency.

Changing citizens' awareness of their everyday environment, in the light of their own priorities and goals, creates a new possibility for the prevention of lifestyle related diseases and, indeed, for the co-production of health and reduction of potential chronic, life quality reducing and costly health conditions and complications.

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