Design of a Framework for Wellness Determination and Subsequent Recommendation with Personal Informatics

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Abstract

Due to the advances in medical science, increasing health consciousness, improved quality of food, the average human life span has increased to a great extent. On the other hand, stresses of modern life, overwork and less sleep, increased usage of digital devices and internet, less exercise, are leading us to poor quality of life. Elderly people are more vulnerable to reduced life quality due to deterioration of both physical and mental health. People at any age need to maintain a minimum level of wellbeing to pursue his or her daily activities to lead a fulfilling life. Thus the need of assessing and restoring wellness is very important. Fortunately the progress of information and communication technologies provide use sensor devices and computing platform to feel, monitor and restore the wellness. In this work, a study has been done to define and determine wellness related to daily activities data obtained from various sensors and provide recommendation to the user regarding improvement of life style to achieve wellness. A small-scale experiment has been done using a simple lifelog device. The daily activities data including walking steps, sleep time, inactive period, calories burned are collected from 8 subjects. In addition food intake, eating times, cell phone usage, messaging time, time of interaction with other people and solo time are also manually collected. The correlation of physical activities (walking time, exercise time), mental activities (cell phone usage, study time, interaction with friends) and sleep patterns are studied. A simple parameter *Tiredness Factor* has been proposed to determine wellness and a recommendation system for improving wellness has been developed. Questionnaire from the subjects about the personal feelings of wellness has been noted and used to evaluate our proposal.

Introduction

With the improvement in medical and health science, people are now able to enjoy long life. But stresses of modern life, overwork and less sleep, eating habit and sedentary lifestyle lead to poor quality of life. It seems that quality of physical and mental activity has a profound impact on quality of life. With the aging, physical and mental health deteriorate, leading to a sense of reduced wellness. The quantitative definition or assessment of wellness to visualize the direct relationship of daily activities on quality of life, or ones wellbeing, is difficult to achieve.

On the other hand with the expansion of information and communication technologies, proliferation of mobile digital devices like smartphones and various sensors, ever increasing appeal of online social media, real time collection and processing of personal data related to one's health, physical and mental, are becoming quite practical. Analysis of various sensor data attached to a person's body or environment, may reveal a way to visualize the wellbeing of the person (Suryadevara et.al. 2013). Varieties of life logging devices are now available in the market which can record daily activities and many sorts of physiological data which can be used for many purposes. Activities on social network, blogging, face book status updates, etc. provide us opportunities for assessment of mental and emotional states.

The wellness or the state of wellbeing of a person is related to quality of life and everybody needs to maintain a minimum level of wellness to pursue his or her daily activities. The level of wellness affects the quality of daily activities and achievements of a person while the daily activities or acheivements affect well being of a person. According to WHO (World Health Organization) wellness is defined as *"an active process of becoming aware and making choice toward a healthy and fulfilling life, .. a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"*. Though the concept of wellness is multidimensional (according to Charles B. Corbin of Arizona State University), the two main categories are physical and mental wellbeing. The conscious effort of a person to exploit his or her full potential in daily living constitutes wellness. There are several studies on wellness, yet there is no universally accepted answer for its definition or method of assessment or improvement.

The objective of this work is to study for developing a framework for defining wellness by relating it to the daily activities of the person, proposing a method for quantizing or assessing wellness in terms of measurable personal health (physical and mental) data and finally proposing a recommendation system for improvement of wellness of a person. The next section deals with the concept, definition and development of wellness as studied so far in the related literature. The following section represents an account of reserach works on wellness determination and recommendation for healthy living followed by the proposal of our framework for wellness assessment and how it can be used for personal

health and wellness improvement . In the next section, a pilot study using simple life log device has been described followed by the results of the study. The final section concludes the paper with mention of the current status of the work and future direction.

Wellness: Definition and Development

The concept of wellness originated in the ancient world. Its practice spread in different old civilizations (Greek, Indian, Chenese) with a goal to maintain the harmony of body, mind and spirit. In 19th century, a number of alternative healthcare methods that focus on self-healing, holistic approaches, and preventive care including homeopathy, osteopathy, chiropractic, and naturopathy received widespread popularity in both Europe and the United States.

The modern use of the word wellness gained momentum around mid twentieth century. In the seminal work of physician (also with statistics background) Halbert Louis Dunn defined *High-level Wellness* as *an integrated method of functioning which is oriented toward maximizing the potential of which the individual is capable. It requires that the individual maintain a continuum of balance and purposeful direction within the environment where he is functioning* (Dunn 1961: 4-5). Dunn's idea was initially received little attention except in a very few work like in (Kaufmann 1963), but was embraced by an informal network of individuals in the U.S., including Dr. John Travis, Don Ardell, Dr. Bill Hettler, and others around 1970 (http://www.globalwellnessinstitute.org/history-of-wellness/). They proposed their own comprehensive models of wellness, developed new wellness assessment tools, and wrote and spoke actively on the concept. Travis, Ardell, Hettler and their associates established the National Wellness Institute and National Wellness Conference in the U.S.

Dr. Bill Hettler developed the model of wellness having six dimensions: Occupational, Physical, Social, Intellectual, Emotional and Spiritual (http://c.ymcdn.com/sites/www.nationalwellness.org/resource/resmgr/docssixdimensionsfactsheet.pdf). By applying this model, an individual becomes aware of the interconnectedness of each dimension and how they contribute to healthy living. Towards the end of twintieth century, attainment of wellness started taking seriously by medical, academic and corporate worlds as well as by government. The concept of healthy lifestyle grew among general public and corporations, universities and government started to develop many wellness promotion programs. With the increasing technological marvels of 21st century, advancement of artificial intelligence(AI), proliferation of digital devices on onehand, chronic diseases, obesity, unsustainable health care cost are also increasing. People are moving more towards traditional medical care to maintaining wellness by changing lifestyle.

As longevity of people has also been increased, taking care of the old people is becoming a serious issue in our super aging society. Care givers to the old people more and more rely on new technologies for automatic assessment of wellness of the people whom they take care of. Governments in the devolped and developing countries are also now keen to promote health related activities to improve the quality of life of their citizens. Now the evolving information and communication technologies along with AI techniqus can be judiciously used to support the society for improving the wellness. Thus the need of assessing wellness of a person and the ways for its improvement is now keenly felt. Researches are going on for the assessment of wellness and how it can be used to monitor and improve people's daily life with the help of newly evolving technologies, but yet to take a definite shape. Some of the related researches are described in the next section.

Wellness Determination and Recommendation for Healthy living

Ubiquitous computing is shifting the traditional treatment for diseases in hospitals to self care, home care and preventive care in order to lead a more fulfilling life. Due to increased life span in modern era, taking care of elderly poses a burden to health care system. Health care experts now feel that financial impact can be lowerd by providing assisted living environment with the help of pervasive computing. Home monitoring systems are now being developed to assist eldery to assess their peronal wellbeing.

In a series of work (Suryadevara et.al 2012) (Suryadevara et. al. 2012a) (Suryadevara et.al 2013) (Suryadevara et. al. 2014), the authors proposed a method of wellness determination of the elderly living in ambient assisted living environment by monitoring their daily activities. They proposed two indicators β_1 and β_2 known as *wellness functions*. β_1 is related to the index level for inactive household objects and β_2 determines the index level for excess use of a household object. Both the functions indicate some changes in routine activities that can be related to wellness of the elderly person being monitored. They built a prototype and could evaluate the effectiveness of their proposals.

Development of personalized health care system is another direction of research gaining increasing attention. The infrastructure of a personalized healthcare to motivate self care for healthy living is outlined in (Zhang et. al. 2004) (Lin et. al. 2011). Mobile devices like smartphones, GPS, lifelog devices are used to record daily activities of individual and numerous services are developed for supporting individual's wellbeing. In (Tanaka et.al. 2015) , a method for generating high quality lifelogs by using GPS sensor is presented. The user can look back his daily detail through mobile phone applications/services and can use the data for self assessment for improved life style. Other studies for lifelog data collection can be found in (Ono et.al. 2010), (Abe et.al 2012) (Martin et. al 2013) . One of the main use of lifelog data is in the area of health care by modelling personal life style and providing feedback or recommendation for healthy living and prevent life style related diseases.

There are some studies on stress detection from unobtrusive sensors instead of obtrusive physiological sensors by using mobile phone. User's mobile phone behaviour provides stress level, mental health and social well being which can be used to assess overall wellness of a person (Bogmolov
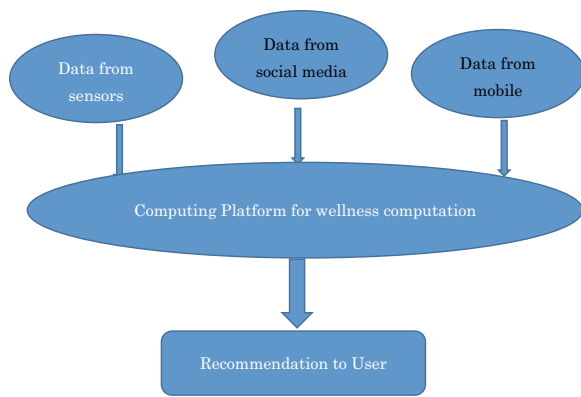
Figure 1: Block diagram of the proposed system

et. al. 2014). Data mining technogies are used to develop and manage healthcare information system to build health recommendation system (Duan et. al. 2011). Recommender system for wellness is developed in (Lim et.al. 2013) , but the approach is different from our proposal. In Lim's approach, recommender system helps user in finding similar cases from internet and provides suggestion. Recently the explosion of big data and cloud technogies provide the opportunity for managing the computation of various sensor data and produce recommendation for high quality living. Various projects in different countries are undertaken in this direction. A global healthcare policy is emerging with a shift from volume based hospital centric model of health care to value based individual patient centric information technology (IT) and artificial intelligence (AI) based healthy living.

Proposed Framework for Improved Wellness Recommendation System

In this section our proposed framework is presented as shown in Figure 1. The modern wellness model as presented in the earlier section is considered to be six dimensional, though the dimensions are interconnected. Among the six dimensions, occupational dimension recognizes personal satisfaction through work life, i,e related to one's career. Physical dimension seems to be the most relevant and easy to accumulate in the wellness measure. It can be realized by encouraging proper nutrition, exercise and sleep while discouraging unhealthy food and habits like tobacco, drug or excessive alcohol. Social dimension is related to one's environment and interaction with society and community, contribution to and sense of existence in the society enhances wellness while confrontation with the environment reduces wellness. The fourth dimension, intellectual dimension recognizes creativity and productiveness. Spiritual dimension is related to one's search for soul and meaning for existence, Emotional dimension reconizes awareness and acceptance of our feelings. Now consideration of the individual dimension independently is difficult. In this study, we consider three main dimensions *Physical*, the most prominent one, *Social* and *Mental* which encompasses Spiritual, Emotional, Intellectual and Occupational dimensions.

Now to measure the wellness of a person we would like to propose to collect data from three sources as shown in Figure1.

1. Data from physical or physiological sensors attached to the body of the person for measuring physical wellness.

2. Data from mobile devices used by the person for assessment of behavioral pattern that can contribute to the mental wellness.

3. Data from online social media (facebook, twitter, blog) used by the person for assessment of personal and social behavior of the person that con contribute partly to mental and partly to social wellness.

A computing platform is necessary for the integration of the information. Datamining and machine learning techniques are to be used for knowledge extraction from the data and finally the wellness value has to be calculated from the knowledge based on prior definition of wellness in terms of measured data. The personal model of wellness is to be built over the knoledge from the data taken over a considerable period of time. Perceptible deviation from the normal values of a person and also from the standard values are to be recognized as abnormal or unwell condition. The cause behind this deviation is to be estimated by considering correlation of several factors related to wellness and the remedy should be fed back to the user as a recommendation for restoring wellness.

A Pilot Study with Lifelog Device

A pilot experimental study has been done using two simple life log devices ,UP Jawbone activity tracker (https://jawbone.com/up) and fitbit flex (https://www.fitbit.com/jp/flex). These devices can collect follwing data of daily activities

- Walking steps
- Sleep time (REM and non REM sleep)
- Time for inactive period
- Time for highly active period
- Calories burned

8 subjects (undergraduate and graduate students of our university) at the age group of 20-24 were selected for collection of data for a period of 45 days. Each of them wore the devices in their wrist for 24 hrs and the data were logged in the mobile phone using bluetooth technology. In addition, all subjects were asked to keep a memo /diary of food intake and eating times, cell phone usage , time of interaction with other people. The sensors data and these manually taken data has been integrated for analysis. Also subjects were asked to keep a note of their personal feelings regarding wellness. These notes were used as a ground truth for evaluation of the system. The data taken by the devices are shown in Fig 2.

The correlation of physical activities and sleep patterns are studied. A simple parameter *tiredness factor* TF has been proposed for measuring tiredness of the subject. Tiredness factor is considered to be inversely proportional to wellness.

AJ	AK	AL	AM	AN	AO	AP	AQ
m_active_time	m_calories	m_distance	m_inactive_time	m_lcat	m_lcit	m_steps	m_total_calorie
3,616	209.7350005	5,168	27,720	1,262	5,760	6,870	1791.564111
4,124	248.2289996	6,128	28,020	1,075	7,980	7,962	1830.039604
3,953	217.311	5,335	20,400	1,390	5,280	7,235	1799.103097
4,165	235.1220006	5,861	27,480	1,636	16,200	7,615	1816.895591
5,012	291.8050008	7,171	28,940	1,405	6,180	9,493	1873.560084
							1581.736577
6,488	524.2120014	11,432	20,340	1,767	7,140	13,664	2105.930071

Figure 2: Data logged by the device

It has been found that tiredness factor is influenced by high physical or mental activities and less sleep.

A personal model of each subject is developed with the data for 30days for normal activities and normal sleep (the average over one month's data has been considered as the normal). A threshhold for each subject is selected depending on the standard deviation of the tiredness factor data of the same person and the standard value of the tiredness factor data (taken as the average over all subjects).

The next 15 days data has been used for recommendation. Tiredness factor of each day and for each subject is calculated and if it crosses the threshold, the system recommends the subject to take rest or extend sleep hours. Finally the subjects were asked to figure out the most tiring days by their own personal feelings to verify whether it matches with the oucome of the recommender system.

The tiredness factor (TF) for a particular day "T" is calculated as:

$$TF = \frac{1}{\sqrt{(M_{mean} - M_T)^2 + (S_{mean} - S_T)^2}} \quad (1)$$

where M_{mean}, S_{mean}, M_T and S_T represent average excercise value (calculated over activities data), average sleep time , excercise value of day T and sleep time of day T respectively.

Now M excercise value at any day i and S sleep time at any day i are calculated as

$M_i = w_i * \frac{a_i}{a_i + r_i}$

$S_i = s_i * \frac{l_i}{d_i + l_i}$

where a = active time, r = inactive time, s = total sleep time , l = REM sleep time D = non REM sleep time. All values are normalized to take values from 0 to 1.

The Table 1. represents the tiredness factor of a particular day for 5 subjects taking into account only the personal model. Table2. represents the tiredness factor of a particular day for same 5 subjects when the deviation is calculated taking into account the average value of 5 subjects. It seems that for person E the value of Tdoes not change much while for other persons the value of TF changes a lot depending on the way of calculation. The evaluation with the ground truth reveals that the TF matches with the personal feelings when TF is calculated according to personal model.

Table 1: Wellness determination based on personal model

Subject	value of M	Value of S	Value of TF
A	0.288	-0.763	0.687
B	0.143	0.593	0.913
C	0.801	0.849	1.171
E	0.523	0.1.149	0.793
F	0.160	0.0440	0.419

Table 2: Wellness determination related to all subjects

Subject	value of M	Value of S	Value of TF
A	0.254	0.155	1.452
B	0.115	2.801	0.275
C	1.182	0.455	0.663
E	0.560	0.1.548	0.864
F	0.180	0.0274	0.1.166

Conclusion and Future Direction of Work

The concept, definition and determination of wellness in relation to daily activities have been studied in this work. The proliferation of modern technology is enabling us to lead better life in terms satisfaction and fulfillment. Quality of life is expressed in terms of wellness or well being. The assessment of wellness is important to quantify and improve the quality of life. Due to advances of artificial intelligence, data analysis, information and communication technolgies, knowledge extraction from a large volume of sensor data are becoming practical. As a result the global trend of health care is gradually shifting to personalized models of health care to achieve a sense of well being.

A framework of modelling and assessing wellness of a person from various data collected from sensor attached to the body of a person and other sources used by the person is proposed. A simple experiment has been done for assessing only physical wellness with sensor data attached to the body. The results of this experiment shows that wellness can be assessed to some extent automatically from the collected data as evaluated by the ground truth of personal feelings.The pilot experiment needs to be extended to include other information for assessing other dimensions of wellness. The calculation for assessment is also very crude now. It needs to be refined and modified to represent more realisitic asessment. We are currently involved in assessment of wellness value of elderly at home care environment from their daily activities. The wellness value is needed for their monitoring

by care givers. We hope to report results of our study in near future.

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