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Ubiquitous Life People Informatics Engine (U-Life PIE): Wearable Health Promotion System

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Abstract—Since Google launched Google Glass in 2012, numbers of commercial wearable devices were released, such as smart belt, smart band, smart shoes, smart clothes ... etc. However, most of these devices perform as sensors to show the readings of measurements and few of them provide the interactive feedback to the user. Furthermore, these devices are single task devices which are not able to communicate with each other. In this paper a new health promotion system, Ubiquitous Life People Informatics Engine (U-Life PIE), will be presented. This engine consists of People Informatics Engine (PIE) and the interactive user interface. PIE collects all the data from the compatible devices, analyzes this data comprehensively and communicates between devices via various application programming interfaces. All the data and informations are stored on the PIE unit, therefore, the user is able to view the instant and historical data on their mobile devices any time. It also provides the real-time hands-free feedback and instructions through the user interface visually, acoustically and tactilely. These feedback and instructions suggest the user to adjust their posture or habits in order to avoid the physical injuries and prevent illness.

Keywords—Machine learning, user interface, user experience, Internet of things, health promotion.

I. Introduction

THE The human health is influenced by various risk factors [1] including physical activity, diet, sleeping and emotion. Disturbing one of the factors may increase the risk of illness and disease. For example,

- More than 100 million people worldwide are suffering knee osteoarthritis [2] which is a kind of joint disease caused by the long-term of bad posture of gait.
- Two-third of adults in the U.S. are overweight and obesity [3] due to unhealthy diet. Overweight and obesity may leads to hypertension, diabetes, coronary artery disease etc. [3]
- Lack of sleep may causes brain diseases. Recent studies shows, human brain clears out toxic molecular which may induces Alzheimer's and other brain diseases during sleeping [4]. However, more than 30% of adults complain of insomnia [5].
- Immune system and cardiovascular activity are healthier under positive emotional state [6].
- Constantly under pressure may causes mental problems [7].

These risk factors are linked to each other. Disturbing one of the factors effect the other. For example,

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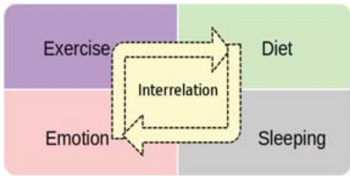


Fig. 1 Health factors: physical activity, diet, sleep and emotion

- The right amount of exercise, for instance, not only enhances the appetite, but also helps sleep and induces central nervous system to produce endorphins [8]. Endorphins inhibits the pain signal transmission and enhance the felling of happiness.
- Unbalance diet causes physiological problem. Low concentration of potassium in the blood causes hypokalaemia which leads to muscle weakness [9]. Conversely, potassium supplement helps sleep better [10].
- Insomnia effects emotion. It causes mental health problem such as depression [11] and paranoia [12].

Due to the interrelation of these four risk factor, medical doctors are needed to evaluate all these factors quantitatively and qualitatively to give the best health advice to their patients. However, these guidance only be given when the medical staffs are presented, i.e. no more health advice when the patients left the hospital.

The wearable computer technology may be the solution. Since Google launched Google Glass in 2012, numbers of commercial wearable electronic devices were released, such as smart belt, smart band, smart shoos, smart clothes ... etc. Some of these devices are applied on health promotion. They monitor and quantify physical and physiological conditions of the user, from heartbeat to brain activity. Some of the devices propose suggestions to the user to guide their movement, posture and behaviours to get the better performance. Swan [13], for example, proposed snowboard training device which measures the offset of centre of mass during the skiing and instantly feedback to the user to adjust the posture. These kinds of devices, indeed, provide readings and give the feedback to the user. However, the feedback is determined only based on the data the devices measured and/or default arguments input by the user. The decisions are made without analysis other factors comprehensively, such as health condition, medical history, physical and physiological conditions of the user while using the devices. This may leads the inaccurate readings and inadequate advises.

The aim of this project is to develop a new health surveillance system, Ubiquitous Life People Informatics

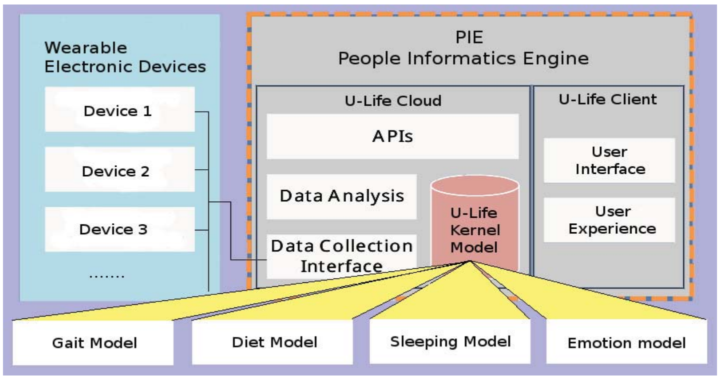


Fig. 2 Structure of Ubiquitous Life People Informatics Engine (U-Life PIE)

Engine (U-Life PIE), which integrate various functional wearable devices. This system not only perform as a data integration which presents the readings measured and collected from devices, but also analyze these data and provide the instant interactive feedback to the user. This feedback indicates the user to adjust their behaviours or habits in order to prevent the physical injuries and prevent illness.

In the next section, the U-Life PIE system will be presented. The section is divided into three subsections: U-Life PIE structure, PIE training and theoretical background, and user interface/user experience. The function and the structure of the system will be discussed the first subsection. The second subsection will introduced the theoretical background and system training method briefly. The user interface/user experience will be discussed in the last subsection.

II. U-Life PIE System

Ubiquitous Life People Informatics Engine (U-Life PIE) consists of two main units, People Informatics Engine (PIE) unit and User Interface/User Experience (UI/UX) unit. The compatible wearable devices are applied to measure physical and physiological data from the user and submit these data to PIE. PIE units analyze the data and deliver feedbacks to user by either acoustic, tactile or visual signals. Since this project aims at the health promotion system, the health factors including diet, physical activity, sleeping and emotion are considered.

A. PIE Unit

The main functions of PIE unit are data collection, data analysis and communication with between devices, in which involves various application programming interfaces (APIs). The data received from all devices are stored in the U-Life Cloud (see Fig. 2). PIE evaluates these data all together and propose guidances based on the analysis results and the historical information of the user, and return to the user interface (e.g. wearable devices and smart phone Apps).

B. PIE Training and Theoretical Background

Before PIE is able to analyze the data received from devices, the system needed to be trained to understand the data. This can be reached by machine learning techniques. The process of machine learning is illustrated in Fig. 3. Firstly, the validated data need to be produced based on domain knowledge and under the supervision by expertise. Three-fourth of the validated data are used for training purpose. Secondly, the learning algorithm such as linear regression, logistic regression and classification are applied. Lastly, the rests of the validated data are used for testing. The theoretical background of those four health factors are discussed in detail below.

Physical Activity Model: In this circumstance, the project focus on the posture of physical activities specify on gait. Knee osteoarthritis (OA) is caused by the high medial knee joint force [14]. This often links to the long-term incorrect gait when walking, the skeleton of the lags and arch index of the subjects. Knee adduction moment (KAM) is one of the key factors which quantify the posture of gait [15]. It is able to reduce the pain for Knee OA patients and slow down ageing of the knee by reducing KAM [16]. Machine learning technique is applied to classify the subjects in to different group of gaits. This may depends on the arch index of their feet, leg axis ... etc.

Diet Model: When user takes a photo for his meal via the U-Life PIE user interface. PIE applied image recognition technique to identify the food and search on the database, such as USDA National Nutrient Database [17], to list the nutrition facts and compute the calories contained. The nutrition absorption by the user can be calculated by comparison with the user's digestive condition. Then diet module follows the analysis to advice the supplements to the user.

Sleeping Model: The sleeping quality can be quantified by measuring the brain activity via electroencephalogram (EEG) during sleep [18]. EEG shows the 4 stage of non-rapid eye movement (non-REM), ranging from the lightest sleep in stage 1 to the deepest sleep in stage 4. The longer period of deep sleep stage indicates the better sleep quality. With regard to the machine learning algorithm, a list of factors which may effect on sleeping, such as diet and exercise, is determined according to the domain knowledge from experts. The training set is a set of input feather (factors) couple with the corresponding sleeping quality (period of sleep in stage 3 and stage 4).

Emotion Model: Emotion of a person can be measured from the heart rate, respiratory rate [19], EEG and observed by

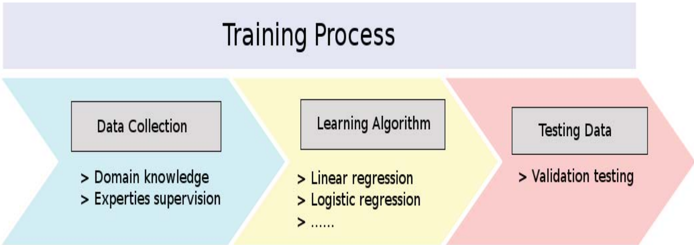
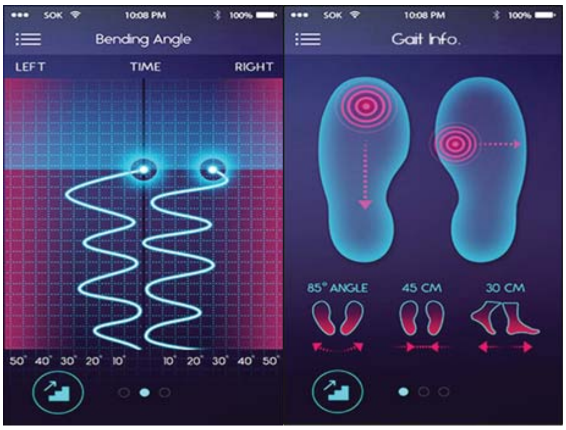


Fig. 3 PIE training process

Fig. 4 Hands-free feedback delivers to insoles and kneepad by vibrations and lightening



(a) (b)

Fig. 5 Instant feedback informations display on mobile devices. This shows the (a) bending angle of knees and (b) centre of pressure on the foot, progression angle, stride length and width

(a) (b)

Fig. 6 Historical data display on mobile devices. (a) Average pressure distribution. (b) Average knee stress position

facial expression [20]. Similar to sleeping model, model of emotion can be trained by the training sets which the input features are determined by domain knowledge provided from experts and the targets are the emotion measured by heart rate, respiration rate and EEG.

C. PIE User Interface/User Experience

The U-Life PIE user interface consists of data display and the feedback from devices. The data display is designed as an App for smart phones and tablets. The user is able to monitor their instant and historical data from their mobile devices at any time. According to the user experience, the user may not able to check their devices frequently. U-Life PIE offers the hands-free signal, such as vibration and lightening, to deliver the instant feedback to the user in order to provide the guidances or advices to the user.

In the case of physical activity analysis in PIE, as an example, we designed a set of smart footwear 4. This smart footwear aims to improve the gait of the user in order to avoid knee OA and reduce the pain for knee OA patients. U-Life PIE calculates knee adduction moment (KAM) by measurements of pressure distribution on the foot, knee joint stress distribution, foot progression angle, stride length etc. The PIE unit provides the gait correction advices to the user based on KAM. These informations are showed to the mobile devices instantly and historically (Figs. 5 and 6). The instant hands-free feedbacks are return to the user by OLED lightening signals and the various patterns of vibration. For instance, the OLED lights are attached on the kneepad to warn the user the high stress on the knee joint (Fig. 6 (b)). The smart insoles with four vibration motors indicate the direction suggestion to the user in order to correct their gait and move their centre of pressure towards to the appropriate location on the foot (Fig. 6 (a)) .

III. Summary

In this project we propose a new health promotion system, Ubiquitous Life People Informatics Engine (U-Life PIE), which not only perform as a data integration, but also analyze these data and provide the real-time interactive feedback to the user. User may follows the suggestion to adjust their behaviours or habits in order to prevent the physical injuries and prevent illness. In this circumstance, People Informatics Engine (PIE) focus on four risk factors for health including physical activity, diet, sleeping and personal emotion, as well as their interrelation. The various functional compatible wearable devices are able to applied to collect the necessary data and submitted to PIE unit. PIE unit integrates, analyzes and evaluates these data comprehensively, and provides suggestions to the user base on their psychological and physiological conditions. This new system not only improves signal task problem of transitional wearable electronic devices, but also improves the accuracy of the readings by considering comprehensive personal information.

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