Converting Data to Actionable Health Information

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Abstract
Each individual is a unique entity. We consider this uniqueness to be an important precondition for turning self tracking tools into perpetual health management systems. The tracking data itself cannot describe this uniqueness. However, actionable information based on a personal model which reflects these unique characteristics would have a strong impact on individual's life through behavioral modifications. In this paper, we are developing an approach for future health system based on perpetual yet unobtrusive guidance for lifestyle and behavioral adjustments. This approach uses cybernetics principles for providing the right information at the right time in the right situation using the right influence mechanisms. Our experiments involve working with medical experts to deploy these systems in perpetual health management.

Author Keywords
Long term self tracking, Cybernetics health, Personal model, Personicle

ACM Classification Keywords
H.5.1 [Information interfaces and presentation (e.g., HCI)]: Multimedia Information Systems.

Introduction

The popularization of smartphones and wearable devices encouraged people to consider self tracking for personal health and well-being. Following this trend, potential opportunities for long term self tracking, such as identification of trends and relationships which can facilitate informed decision making, were highly expected [10, 9]. However, one major impediment to this belief was that self tracking data had had no significant impact on users' lives, and thus the users abandoned the tracking even at early stages [2, 3, 4, 8]. To keep users motivated, self tracking data should become actionable information based on the understanding of each individual. The data itself only represents very little, but actionable information can provide useful insight to improve quality of life. More importantly, this information should be provided at the right time in the right situation, and in the right way by using emerging wearable, mobile, and social sensors. We believe that ideas and methodology from cybernetics may be useful in building such infrastructure.

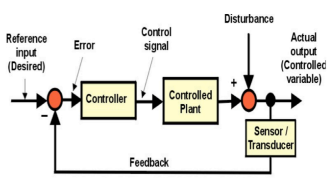

Figure 1: Feedback control on cybernetics system.

Cybernetics is an approach for control and communication in both machine and living systems by continuously measuring changes, estimating current states, and using the difference in desired and current states in a closed-loop feedback control system (Figure 1) [15]. Navigation systems, such as Google Maps, are good examples of cybernetic systems which transform a navigation system from 'nice-to-have' to 'must have'. About a decade ago, maps were a planning system used before undertaking travel and occasionally during the trip. With the arrival of GPS and the development of *Waze* like approaches [1], maps have become a perpetual navigation system, which use GPS to measure current state, compare it to the destination, and plan and guide about the route based on current traffic situations. This loop is repeated until a driver arrives at their destination.

Feedback regulation also occurs in the human body to maintain homeostasis. When the internal cybernetic systems fail to function properly, the human body enters the disease state needing external help to reinstate homeostasis. We are interested in involving this feedback regulation of the human body in helping the internal cybernetic system to work properly, and thus guiding one's ability to live a health life. In this paper, we first present Personal Health Navigator (PHN), which reflects cybernetics principles to the perpetual health management system. We then discuss how tracking data can be developed into a personal model, actionable health information, and influential guidance to affect users' lives.

Personal Health Navigator

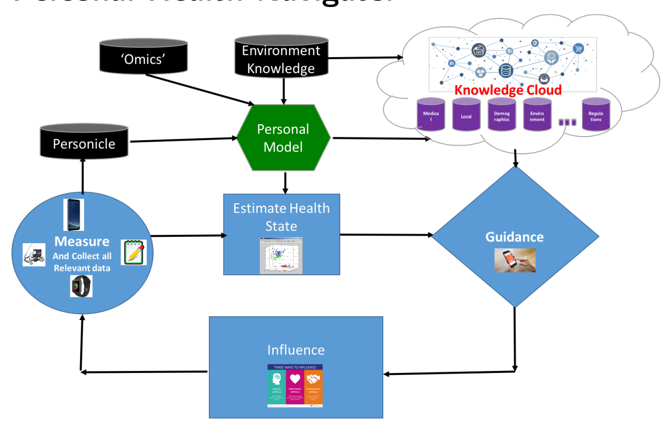

Figure 2: The cybernetized Measure, Estimation, Guidance, and Influence (MEGI) cycle.

In current health practice, doctors estimate one's health state based on biomarkers, such as vital-signs, blood tests, imaging, and pathology reports to diagnose a case. PHN

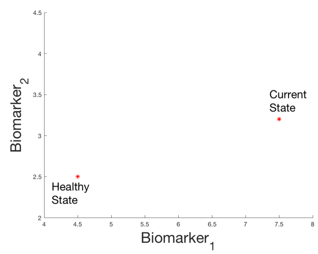

Figure 3: Health state dimension. Current health state is estimated, and desired state is set up.

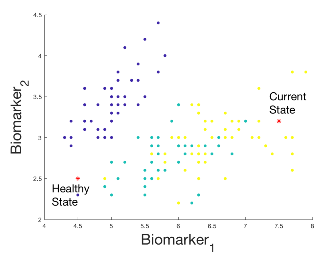

Figure 4: Overlaying relational biomarkers of each case on health state dimension. It indicates proximity to each disease.

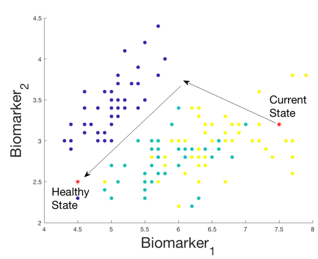

Figure 5: Health navigation. PHN navigates current health state to the desired health state.

also focuses on estimating a current health state by perpetually measuring those biomarkers, and thus indicating proximity to each disease. Along with this, PHN tries to provide situationally actionable and easy to follow guidelines in order to direct people in achieving their desired state. We cybernetize this whole process by using the Measure, Estimate, Guide, and Influence (MEGI) cycle [5] in a closed-loop feedback control (Figure 2).

Measurement
The measurement of the MEGI cycle seeks to fully automate the tracking process by developing a sophisticated self tracking tool [13, 14, 12]. We automatically measure as many low level data streams as possible in the daily lives of people, and try to infer semantic level events, such as daily activity (e.g., working, eating, or exercising) [7], which can provide an intuitive grasp of their life.

Estimation
Disease centric estimation would result in biased decisions that can disrupt objective understandings of one's health. Therefore, we aim to estimate personal health state with all of the measurements, and indicate proximity to each disease, as shown in Figure 3, and Figure 4. To do that, we build a personal model, which includes lifestyle, environment, socio-economic factors, and even genetic information for each individual, by considering omics, medical and environmental knowledge, and *Personicle*, which chronicles personal daily activity [13, 6].

Guidance
The guidance phase induces people to achieve a desired state in the closed-loop feedback control (Figure 2). We combine medical, environmental, and other relevant knowledge (e.g., demographics, or regulations) with the personal model in order to recommend health-oriented actions. These guidances would be a type of change in lifestyle, environment, intake of medication, regimens, or other treatments, and thus try to incrementally cause improvements in their current health state. This guidance also would continuously reflect how the user has implemented recommendations, and provide additional guidances until the user reaches the safe zone, or as far as possible from disease.

Influence and Compliance
We think that guidance, such as prescription, standard regimens, or behavioral changes, is not enough to induce improvement in overall health. Therefore, in this study, guidance will be provided as an achievable action based on an individual's context and preferences, and will be easy to implement and follow.

Based on these individual contexts and preferences [11], We try to perpetually persuade people to induce minimal changes, which are good for health, and thus keep rerouting the current state to the desired state as in Figure 5.

Data to Personal Model
PHN requires a personal model to estimate the health state of each individual and provides personalized guidance. There was a difficulty in comprehending one's uniqueness, such as different lifestyles, environment, and socio-economic factors, when we only utilized low-level data. Thus, we have defined a concept named *Personicle*, which chronicles daily activity with informational features, and tries to covert low level data to semantic level personal daily event. We first measure lifelogs, including physical activity, step, location, or phone oriented data (e.g., application and media usage, photo, or calendar), and then recognize the 24 most common daily activities

such as "sleeping", "commuting", "working", or "eating" [13, 7] in the measurement phase. Then we form *Personicle* by enriching the chronicle of daily activity with biomarkers (e.g., heart rate, blood pressure, stress level, or glucose level) and environmental conditions (e.g., weather, or air quality), for example "sleeping;average resting heart rate;good quality sleep", "commuting;walking;talking to friend(s);warm weather;low stress level". The personal model is based on this *Personicle* to capture how a person reacts to different stimuli under specific conditions. The personal model also trains omics and medical knowledge in order to analyze a person on the genetic level.

Actionable Information to Perpetual

PHN estimates the current health state of each individual based on their personal model, and measures the proximity of disease as shown in Figure 4. Then, PHN provides actionable health information that can help to avoid adjacent disease, and thus guide people to achieve the desired health state (Figure 5). It starts by suggesting trivial changes. Then, it tracks the people's reactions, measures the changes in their health, and estimates their current health state again. The users may sometimes decide not to follow the guidances, and this may bring about the deterioration of their health. We reflect this case to the personal model, try to reroute their optimal paths by avoiding previous failed guidance, and provide new guidance to navigate them to the desired health state (Figure 2). We pay attention to reactions of the users caused by actionable information in order to perpetually circulate the cybernetized MEGI cycle. We are already working with UCI diabetes clinic to control this disease using lifestyle and behavioral changes suggested by our system. We aim to start working from well motivated and serious patients, to the next level of patients in need, and then to more general users.

Addressing Challenges

Converting data from low level to high level, and incorporating it into the personal model and actionable information is a challenging process. Fully automated tracking may need more meaningful data to diversify daily activity recognition as well as to build a robust personal model. Modeling a person may take a long time to collect quantitative and objective measurements and difficulties may arise when reflecting dynamic changes in the data. People might be disappointed in the actionable information, and then permanently give up participating in self tracking. People also might be reluctant to follow the guidance even though we try to induce minimal changes.

Conclusion

Current self tracking tools have mainly focused on visualization of the collected data rather than providing actual help. This has caused the users, who fail to take advantage of the collected data, to drop out of self tracking. We are eager to move towards lifelong self tracking by providing actual help for people. We are certain that converting data to actionable health information, and perpetuating the cycle in the cybernetized PHN would help to achieve this goal. As part of this effort, we are working with a combination of ten medical, and tech companies to design a complete platform for building PHN. We also bring collaborators from various fields, such as medical science, human computer interaction, and computer science, in the PHN team. We first target serious diabetic patients to perpetually manage their health state, and try to make the transition from early trial and mid term use to long term use of the self tracking tool. In the future, we plan to extend the scope to more diverse disease cases and finally to the general public.

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