Vigilance: Verified InvestiGatIve Lifestyle Analysis and Coordination Environment

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Diabetes is a family of diseases that impacts how the human body produces and uses insulin. As a result, the blood glucose levels of patients with diabetes can vary significantly. If left unchecked and unregulated, such variations can lead to complications in a vast diversity of the body's systems (vision, hearing, skin, nervous, cardiovascular, and others) as well as to death. Given the large and growing number of children and adults with diabetes (+26 million, up +27% over 2007), the burdens its management inflicts on its victims, the challenges it imposes on the medical profession, and its significant cost (+$245 billion in the US), new approaches that help patients maintain stable blood glucose levels are urgently needed.

The goal of our work, as depicted in Figure 1, is to investigate new research for secure and customizable lifestyle tracking and analysis. In particular, we propose a unified system called VIGILANCE that provides

- Secure collection and storage of patient data, including patient vital signs, blood glucose levels, daily activities, etc., from a variety of personal devices,
- Automatic data analysis and personal notifications (alerts, reminders, encouragement, and healthy suggestions),
- Controlled sharing of VIGILANCE data with authorized physicians and care providers, and
- Large-scale analysis visualization of anonymous multi-patient data (collected by VIGILANCE tracking) that help diabetes researchers and doctors discover opportunities for combating the disease quickly.

To enable this, VIGILANCE requires novel research advances in three primary areas: (i) Coordinated data ingress from disparate, independent measurement and tracking sources, (ii) secure and controlled data transmission, storage, and sharing, (iii) and scalable and collaborative data-analytic cloud computing. We also plan for VIGILANCE to be easy to use by patients of all ages and to integrate transparently into their lives and personal technologies (smart phones, tablets, home computers, etc.).

Our research group is investigating the necessary constituent technologies and to design and develop VIGILANCE as part of this effort.

Figure 1: VIGILANCE system overview.

Data Collection and Device Coordination Key to our approach is a personal cloud computing system through which a patient's lifestyle tracking data is securely collected, stored, and managed. We plan to integrate off-the-shelf devices (heart rate monitors, pedometers, smart phone devices (cameras, accelerometers, GPS), home electronics (e.g. televisions), appliances (e.g. refrigerators), and personal computers) as well as evolving glucose monitoring devices into a local, personal, multi-device platform for behavioral tracking and analysis. We plan to collect vital statistics, location and motion data, eating patterns, glucose levels, and a wide variety of other activities and statistics; we plan to work closely with SDRI and diabetes patients to continuously identify and evaluate metrics and their utility and analytic efficacy. Our personal cloud system will automatically analyze this data and send notifications (to the patient's devices) when anomalies and surpassed thresholds are detected. VIGILANCE will also provide and regular reports and visualizations of behavioral patterns and their impact on vital signs, glucose levels, and other metrics in an effort to give patients a better understanding of their decisions and their disease.

Large-Scale Data Sharing and Analysis Patient personal clouds will communicate and share data with a remote public or private cloud system over a secure channel. We will investigate the frequency with which this data is transmitted to prevent data loss, to relieve storage pressure on personal clouds and battery drain on mobile devices, and to ensure that researchers and doctors have access to data in a timely fashion. To enable this, we will classify different data types and metric thresholds, and assign priorities to data with different levels of importance. Important data (e.g. an unsafe glucose level) will be transmitted in near-real-time to enable doctors and care takers to be alerted and respond if needed. Other data will be transformed for easy analytics (database queries and map-reduce processing). Moreover our analytics platform will enable researchers to extend the system with new algorithms for data processing, machine learning, analysis, and prediction, easily. By combining anonymized data across very large numbers of patients (i.e. a form of crowd-sourcing), we and other researchers can employ this collaborative analytics platform to identify patterns (improvements and degradations) as well as correlations between metrics.

Securing and Anonymizing Data The success of our approach relies on novel advances in security and privacy of data. Our techniques will include secure collection, communication, and anonymization and needed within individual devices, across a patient's personal cloud, and between the patient's personal cloud and the public or private cloud used for multi-patient large scale analytics. We plan to investigate new security and privacy mechanisms for access control, encryption, static and dynamic leak detection and prevention at the programming language level (applications on individual devices), at the operating system level (using recent advances in virtualization), at the cloud platform level (within a personal cloud and between cloud services), and at the cloud infrastructure level (for tightly coupled interoperation between personal and collaborative/analytics clouds).