

# Clinico-Environmental System for Personal Monitoring

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**Abstract.** The ever-growing use of information and communication technologies in the past decades and the proliferation of mobile devices for monitoring vital signs and physical activity is enhancing the emergence of a new healthcare paradigm. More recently, citizens are becoming more sensible to the necessity of monitoring environmental health indicators and to its direct impact on personal health. This article proposes and describes the development of a clinico-environmental system for personal monitoring. The result is ContinuousCare, a personal healthcare information system that integrates personal smart devices with air quality monitors. The solution helps citizens to better understand their health and body activity with environmental context, aiding professional doctors with analysis tools and making available valuable data for external systems.

**Keywords.** clinico-environmental monitoring, health monitoring, personal health record, geolocation tracking

## 1. Introduction

The use of science and technology in medicine has been explored by mankind throughout the last decade more than ever. Information and communication technologies brought a proliferation of mobile devices for monitoring vital signs and physical activities of citizens and, consequently, the emergence of a new paradigm of medical monitoring is growing in the research communities.

On one hand, there already exists software to integrate distinct types of health monitoring devices and make available useful tools for injury detection and alert, amongst other purposes. Its target audiences are mostly specific groups like elderly people or athletes. On the other hand, the environmental conditions surrounding human life is often neglected by these healthcare technologies. Health disorders, painful conditions or even diseases can be directly correlated with local environmental conditions such as, for instance, high carbon dioxide levels. Current software solutions do not integrate environmental indicators, neglecting in consequence an important source of data that has tremendous potential to increase the prevention and diagnosis capabilities.

In this paper, we propose a personal monitoring solution called ContinuousCare that is able to integrate traditional personal health monitoring devices and environmental data sources, including home devices for air monitoring. Our system approaches the problem considering both the human activity and the environment it is exposed to and proposes powerful forms of data aggregation and visualization.

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## 2. Background

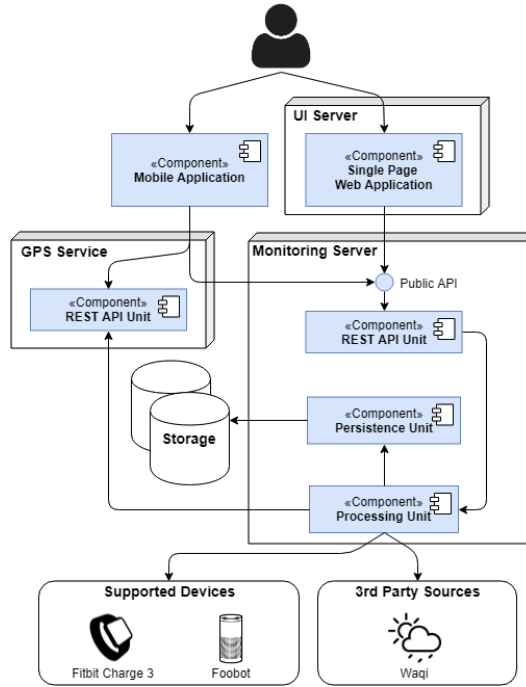
A market research and literature reviewing process was performed for evaluation of actual proposal in the scope of ContinuousCare solution. It is possible to find a tremendous number of products, services and reports related to personal health monitoring, including geolocation recording. Due to the article size restrictions, we just report the ones that were more inspiring to the proposed system. An android application [1], developed by Turkish researchers, was the first product that takes advantage of geolocation to improve its service's quality. The application allowed users to keep track of elderly family members and be notified in case of emergencies, providing the closest hospitals. Health Tracking system [2] used GPS coordinates and other metrics to provide insights on the physical conditions of cyclists. The offered services seems very interesting and were inspiring for our proposal, being adapted to a more generalized target audience. Other solutions such as the Angel-Echo [3] or the UPHSM [4] provided us with perspectives on the potential of the subject and on the variety of use-cases and target audiences that could benefit from robust and intuitive health monitoring systems. Finally, the evaluation of key characteristics of already existing products, for similar problems, were taken in consideration during the design of ContinuousCare. A group of students from SSPACE college [5], in India, gave us valuable insights on what are the best metrics to take in consideration when monitoring body status.

## 3. System Architecture

The architecture of proposed personal monitoring system is shown in the Figure 1. The key design decisions aimed to ensure the robustness and scalability of ContinuousCare and its accessibility to any user with an internet connection. These regarded the collecting of data from our different sources, the appropriate storage strategy and the database load and access-time optimizations. It follows a modular structure where each module is replaceable and updates to one component do not imply the refactoring of others. The main component is the Monitoring Server that is divided into 3 functional units:

- Processing – it is responsible for gathering the information from supported devices and public data source APIs. This operation is scheduled, which means that it is executed many times per day. This unit is responsible for doing this scheduling and for processing the data collected (filtering it, assigning labels, and more);
- Persistence – it is responsible for storing all data after processing. It interacts with the database interface and ensures that every field is persisted correctly;
- REST API – it is the component responsible for supporting a REST (REpresentational State Transfer) interface for the system, serving as the entry point for every client application.

The second module is the GPS Service that was implemented since many personal monitoring devices do not provide access to its locations. Since geolocation is a crucial aspect in our proposal, it was necessary to implement from scratch a service responsible for receiving the users' locations and a mobile application that tracks them.



**Figure 1.** Architecture diagram.

In the persistence layer, we adopted a strategy based on a hybrid database. It was designed a relational database model in MySQL for the structured and interconnected data: accounts information, permissions between users, and devices. For the bulk data received from the devices and external sources, it was used a timeseries driven database, implemented with InfluxDB. This second one was found the best technology for our case as it is dedicated to continuous data streams and queries with time intervals. It is this database that feeds most of our web application's features. A system like ContinuoudCare faced problems of big-data and some optimizations were performed, namely keeping in cache the values for a given time interval and periodically writing all the values stored with a batch process. In the long run, the database will hold a big load of data, some of it turning irrelevant as time passes. For this reason, the storage module supports the aggregation data after a defined period of time.

The platform provides a web application that runs on the UI Server and is our main interface with the end-users. It interacts with a public REST API (through the Monitoring Server) and makes use of the supported devices. It was developed with the NuxtJS framework, over VueJS, helping to maintain an intuitive website organization and giving us the possibility of deploying either a Single Page App or a Universal App (where pages are rendered on the server side for a smoother user experience). Several libraries for graphical elements, cookies and web-sockets were used, as well as an HTML template from Colorlib [6] for design purposes.

Finally, the system supports at this moment three types of data providers: 1) personal monitoring device – it was used the Fitbit Charge 3 [7], an advanced fitness tracker that has many health-related metrics. We focused on collecting calories, heart rate and sleep stages, as these present more interesting information for analysis purposes; 2) air quality monitor – it was used Foobot [8], an indoor device able to detect invisible and odorless pollutants that fall into 3 categories (volatile compounds, particulate matter and carbon dioxide), calculates temperature and humidity levels and alerts users about unhealthy activities; 3) public portal with environment indicators – it was used the Waqi<sup>2</sup> public API that allows us to know the level of pollution of a given place on earth. By tracking the geolocation of our users, the system is able to decide whether to collect information from a Foobot or from Waqi according to the distance between the users and their respective air quality monitors.

#### 4. Results

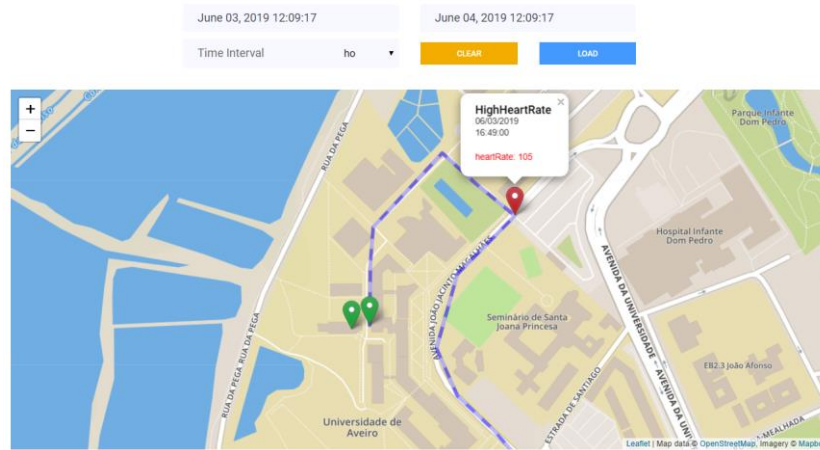
A Web platform was deployed on the Cloud with all functionalities described in this article. The system was continuously used by a user during one month for validation purposes. The platform supports two distinct user profiles, patients and doctors. Doctor accounts, once permitted by patients, have access to the profile information and to all records, grouped by Health Status, Environment, Sleep or Events. In each group, the user can see a particular metric in detail throughout time with the help of the line graphic. The users are able to add, remove or update monitoring devices. For instance, they can have many home devices in different places of common use (home, workplace, etc.).

Users have also available a timeline with relevant events that occur throughout the days. The users can add descriptive markers (annotation) to those events to keep track of their health progress. They include situations like, for instance, heart rate out of the healthy range, presence of high levels of carbon dioxide or other harmful particles, sedentary behaviors (not enough daily steps), few hours of sleep, etc. Figure 2 presents one of the most emblematic functionalities implemented, the History Page here the user can see the places he/she has been, the current location of his/her device(s) and the markers of the events that occurred throughout the defined time window. This allows him/her to pair the events to locations and understand what are the places that affect him/her the most.

The first version of ContinuousCare application provides 7 main functional areas and presents data related to 20 metrics. Its public API provides 26 public endpoints (i.e. services). The results of the scalability tests executed show that the backend supports comfortably 100 users online, each making 300 requests, ensuring all of the performance requirements established.

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<sup>2</sup> <https://waqi.info/>



**Figure 3.** History Page

## 5. Conclusions

Modern society is becoming very sensible to the necessity of monitoring environmental conditions and study its impact on personal health. This paper proposes an innovator clinico-environmental system for personal monitoring. ContinuousCare presents itself as a healthcare tool for any person, empowering both people concerned with their own health and medical personnel looking for innovative analysis tools. It has potential to aid any user interested in perfecting their lifestyle and monitoring the surroundings. It combines data collected by air quality monitors with vital signals from personal health devices, and it makes all data collected easy to read, process and consume in an integrated way. The users can also annotate the detected events and register the daily moods and behaviors. In the future, the efforts will be focused on a new system module for data mining aiming to extract key information from events and offer tools to predict diseases with relatively good confidence and notify users of dangerous behaviors and hazardous environments.

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