An IoT enabled Unobtrusive Worker Health, Well-Being and Functional Ability Monitoring Framework

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Abstract

Maintaining a healthy workforce in an ever increasing and ageing population is of paramount importance in modern western societies. An age-friendly living and working environment is a huge challenge that has only recently started to be addressed as the number of older citizens who are, want or need to continue being active members of society and live independently, is constantly increasing. This paper introduces a system which aims at building a worker-centric Internet of Things enabled system for work ability sustainability, integrating unobtrusive sensing and modelling of the worker state with a suite of novel services for context and worker-aware adaptive work support.

1 Introduction

Population ageing is a huge challenge for most advanced countries. Each country employs its own strategies to increase the presence of older workers in work environments or to reduce the early retirement rates and

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unemployment amongst older people. Especially within the European Union with an employment rate of 55-64 year olds reaching only 55.3% by 2016 [2]. Characterizing a person an "older worker" does not follow any specific definition but in most cases is connected with physical changes that are associated with older ages, and may have resulted in decreased performance in specific physical or mental activities, like decline in vision, hearing. Such conditions can start as early as the age of 50 [5]. At the same time, health chronic conditions tend to be more often in people aged 50+, with almost half the population having hypertension and/or some other chronic disease (e.g. high cholesterol, heart disease, mental illness, diabetes, arthritis, back problems, asthma, COPD, etc.) [1] as a result of the office worker lifestyle. Although the performance of older workers in some physical activities may be declined, their knowledge and experience is what gives them a great advantage over their younger colleagues with regards to mental and experience based tasks and duties [6]. Thus, keeping these workers longer in the workforce can be of benefit to the younger workers that can learn in a more pragmatic way from them and increase the productivity of both.

Our work [3] aims to provide an age-friendly working and living environment through the utilization of an IoT-enabled unobtrusive and ubiquitous framework. We base our design on novel, scalable and viable business models, and also the feedback from large-scale and multi-country pilot applications.

The project will build a Worker-Centric AI System for work ability sustainability, which integrates unobtrusive sensing and modelling of the worker state with a suite of novel services for context and worker-aware adaptive work support. The unobtrusive and pervasive monitoring of health, behaviour, cognitive and emotional status of the worker enables the functional and cognitive decline risk assessment. Towards achieving these goals, the architecture is being built upon existing reference architectures and well-defined practices especially in the domain of AAL. More specifically, it is based upon the Reference Architecture for open AAL platforms of universAAL (which has also been built on existing solutions from previous AAL projects, e.g. IN-LIFE) and by also providing proper extensions to support cloud-based solutions. The architecture takes advantage of interoperability features towards enabling seamless integration of Web services and hardware devices.

2 Architecture

Our work is based on the implementation of a Smart Services Suite that integrates and shares on the various dimensions of the Worker State aware Work Ability modelling to address the needs and requirements of the main user groups. By implementing a suite of smart services instead of a compact system, we aims at achieving a realistic target through the lightweight, on demand, personalized tractable and usable services. The main services included in Our work are:

- Unobtrusive Sensing at the workplace and on-the-move, and low-level heterogeneous data processing algorithms for efficient data transmission.
- A Ubiquitous Workplace, allowing for instant adaptation/personalization and seamless transfer of the computer work environment to the office worker state [7].
- Modelling and Artificial Intelligence for risk assessment on multiple dimensions, related to the work ability of the employee.
- On-the-fly Flexibility and on-Demand Training [4].
- Care Management and Interventions to deliver health and lifestyle self-management services to people with chronic conditions.

The entry point for the unobtrusive sensing infrastructure is a mobile application running on the smartphones of the workers. This application is responsible for communicating in the background with (1) the wearable devices and environmental sensors used by users and (2) the external API services that provide data for the users surroundings (e.g., weather forecasts, or traffic data). This application is called *healthyMe* and will be available for download in all the smartphone application stores supported. All measurements collected from any source in the context of *healthyMe* can then be transferred to the Monitoring Controller of the platform. Once data are collected in the *healthyMe* application they can be parsed, filtered, processed and combined with other data collected at the same time to generate more information that is useful and can be reported at a later stage to the Monitoring Controller. This exchange of messages is implemented based on the best available solution for the operating system used (Android, iOS). Figure 1 presents a simple graphical representation of the interactions between the *healthyMe* application, the unobtrusive sensor network used by the users and the cloud services (internal and third-party).

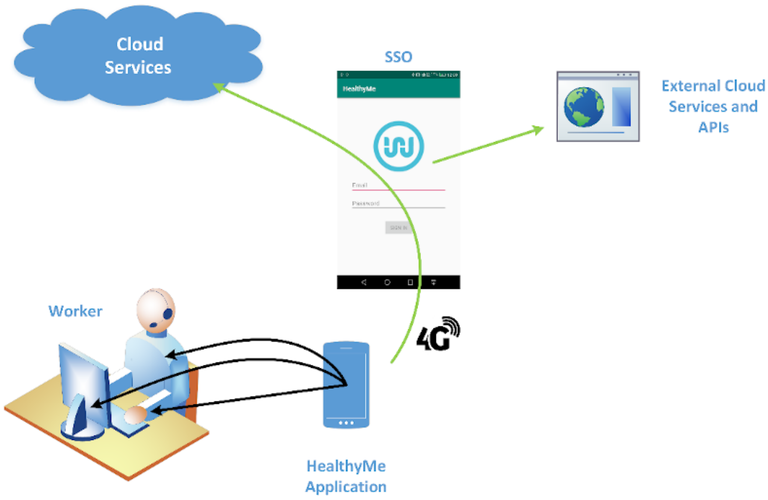

Figure 1: Smartphone application interactions with cloud services and wearable devices.

All sensor data fed to our cloud services are handled by the Monitoring Controller module. This module, is responsible for receiving, filtering, annotating, processing, aggregating, combining, and storing all sensor data, while also providing appropriate APIs to other services. To achieve that and be able to handle any load in the future of the project, the Monitoring Controller is built around a message broker that allows data exchange between its decoupled and loosely related internal services. This module is composed of multiple micro-services that sequentially perform the aforementioned operations on the streams of data received, until the processed data are stored in their final form in the data storage micro-service. In more detail, the service contains the following services:

- Monitoring Controller Queue Service
- Streaming Data Annotation Service
- Streaming Data Filtering Service
- Streaming Data Analytics Service
- Monitoring Controller Storage Service
- Monitoring Controller API Service

Figure 2 shows a graphical representation of the services listed above and their main interactions. We need to note here that although some arrows appear to connect services directly, in most cases this happens through the Queue Service, mainly in the cases where streaming sensor data are exchanged. The only case where services are communicating directly, is the retrieval of historical data by the Rest API from the Storage Service, where the API server directly queries the internal API of the appropriate Storage Service.

Monitoring Controller Queue Service

This service is the heart of the Monitoring Controller. It is pumping data to all the other services in real time and also provides buffering, in times of service failures on networking down-times. It is built around the well-established widely deployed open source RabbitMQ message broker. RabbitMQ allows us to easily decouple the interfaces of other services developed in the monitoring controller and offers flexibility on the technologies used to develop these services due to the huge number of available plugins and client libraries provided by the community. Each user of the platform will be able to publish data, through the User Interfaces like *healthyMe*, to the RabbitMQ broker at a specific exchange. These data are then routed to a list of appropriate queues where their processing and storage takes place. These procedures will be explained in the rest of this section.

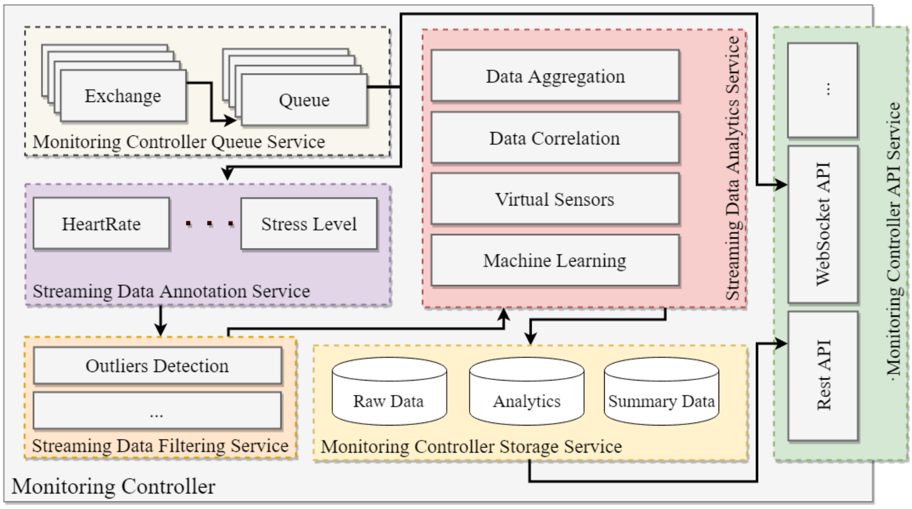

Figure 2: The collected data analysis services and APIs.

Streaming Data Annotation Service

This service is responsible for two main tasks. First it is checking the validity of the origin of the data, making sure that each user is providing data in the appropriate format understood by the rest of the processing services and that the data provided are referring to the current user. The second and more important task is to extract from the naming and the metadata provided by the sender of the data what these data describe. Each sensor measurement sent to the platform should contain at least 3 parameters. The systemName, the value and the timestamp of the measurement. The systemName is a text based identifier that contains information about the owner of the data, and the type of data described in a URI format. The timestamp value is expressed in Unix time (milliseconds since 1/1/1970) and the value is a simple numerical representation of the sensors received data. An example of a sensor measurement is presented in the following example. Based on the sensor data received, the Streaming Data Annotation Service is capable of generating a set of metadata and attaching them to the sensor data object. Such data are the observed phenomenon and the unit of measurement used to express it. In the example presented above, the extracted data would be *Heart Rate* for the observed phenomenon and *Beats Per Minute* for the unit of measurement. These data need to be predefined in the platform so that the Annotation can be successful, and as a result the regular expressions that describe each text pattern needs to be unique so that no annotations cover the same systemName. The generated metadata along with the sensor data are forwarded back to the Queue Service for further analysis and storage.

Streaming Data Filtering Service

The service is responsible for checking the data received for abnormal values and error data that may have eluded any filtering in the Low Level Processing module. It can use both the historical data of the sensor (based on its systemName) and the metadata generated in the previous stem to do the desired filtering. The actual implementation of the filtering is based on the business logic of the application developed and the requirements set up for this specific observed phenomenon with multiple algorithms (e.g., Standard Deviation or IQR Outliers Detection).

Streaming Data Analytics Service

The Analytics Service operation on the streams of data resulting from the Filtering Service and generates time-based analytics and aggregations on the sensor data observed. It is capable of generating different types of analytics based on the observed parameter and analytics on multiple time granularities based on the requirements of the project. Typically, it calculates the average values of the received sensor data on time intervals like 5 minutes, 60 minutes 1 day and 1 month based on requirements observed from previous projects. The service is built around two well established data analytics frameworks, Apache Storm and Apache Flink. Both frameworks are designed for reliably processing unbounded streams of data, and offer easy integration with most queueing and database solutions.

3 Conclusions

In this work we presented the design of a worker-centric IoT enabled ubiquitous work monitoring system as a suite of Novel Services to provide the means for work ability sustainability of the older office worker. The proposed architecture addresses the requirements of the employers, employees and carers helping them to maintain/increase their work efficiency and productivity while also staying aware of their health conditions and needs.

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