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Bio-data collection for a community adaptative work-life balance

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Abstract: With increasing competition and the contemporary multitude of health and wellbeing applications, technology has been continuously challenged to innovate and adapt to increasing usage and complexity. In a growing Internet of Things environment, wearables are everyday use communicating devices able to measure and generate valuable data that can provide insights about a person's physical condition and habits. Ranging from health-related indicators such as blood pressure and heart rate, to more fitness-related values such as steps and calories, these devices are able to collect a considerable amount of data that needs to be filtered, processed and presented to the user with helpful conclusions. This data can be interpreted with a special concern about work-life balance, and to generate community engagement, either in a work or social setting, enabling more user participation and providing dynamic indicators. Citizen Hub is a mobile solution to integrate data from wearables and medical devices, providing features that allow monitoring and managing habits that can greatly impact health and wellbeing. In this paper, insights about work-life balance are explored using Citizen Hub in two different settings, MyWork and MyTime, with the objective of delivering a dynamic and adaptative technological solution for community engagement in a healthy and balanced lifestyle.

Keywords: Wearables, Work-Life Balance, Community Wellbeing, Data Collection, Internet of Things

1. INTRODUCTION

Community wellbeing can be defined as "being well together" (Atkinson *et al.*, 2017). Considering a community as a group of individuals with diverse characteristics who are linked by social ties, share common perspectives and engage in joint action in common geographical locations or settings (MacQueen *et al.*, 2001), to define its wellbeing is to study a combination of indicators that can be of social, health, economic, environmental, cultural or political nature (Wiseman and Brasher, 2008). These indicators can ***promote improvement***, where individuals can be engaged to fulfil their potential and desired quality of life, and establish a contextualized measurement of ***progress*** (Sirgy *et al.*, 2010).

Indicators related to health and fitness have been gaining interest due to the current wide availability of wearables such as smartwatches, biofeedback training devices, medical monitoring devices, fitness tracking and mobile phone-based healthcare applications (Zheng *et al.*, 2013). These are able to collect data on the go and provide the basis for a myriad of health, fitness and wellbeing applications that generate measurable ***insights about a person's physical condition and way of living***. The data from these devices is generally a quantifiable approximation of values based on blood pressure, number of steps, active time, burned calories, distance walked, time with good posture, floors climbed, etc., that can be contextualized and compared, to ***provide helpful conclusions, engagement with others through healthy competition and to help set optimal goals***. This data can allow users to assess their own health (Vijayan *et al.*, 2021) and can also be interpreted with a special concern about **work-life balance**, which is directly linked with perceived happiness (Begüm Ötken and Erben, 2013) and quality of life (Colette Fagan, 2003), where users can gather information from both work and social settings to draw conclusions and insights on how to improve through dynamic indicators and in comparison to their peers.

In this growing Internet of Things (IoT) environment, the potential of wearable's technology and their capability of communicating information, has suffered from the lack of standards adoption (Saleem *et al.*, 2018) and the resiliency of companies of not providing data ownership to users, since data is nowadays considered "the new oil", which means it can be refined into high valued information for businesses and potentially become the biggest exchange commodity (Earley, 2015). For a user to benefit from various devices, it generally must use multiple applications, from multiple vendors. Another important aspect of personal data processing is the implementation of adequate data policies such as the GDPR (European Union, 2016).

Considering these current issues, an approach to allow users to collect and store data on their own terms would be to develop a mobile application that acts as a **hub** and conforms to adequate data policies and commonly used standards, able to seamlessly connect to multiple wearables and devices, and process its information in different contexts, such as in the workplace and while doing everyday activities. The user would be able to get insights on his wellbeing through multiple health and fitness indicators and, if he chooses to share data, compare them with other members of his community.

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In this paper, insights about work-life balance are explored using the Citizen Hub mobile application in two different settings, *MyWork* and *MyTime*, with the objective of delivering an adaptive technological solution for community engagement in a healthy and balanced lifestyle.

2. DATA COLLECTION

Wearables have sensors that provide information about the user's physiology and activity, enabling a quantified self-assessment (Vijayan *et al.*, 2021). This information needs to be filtered, transformed, analysed and processed, to later be reported to the user with helpful insights about wellbeing. To accomplish this, the correct integration of devices and devices' data is key for achieving the success of the methodology. Being a continuous process, several elements for communication must remain active and deal with the heterogenous environment of wearables' behaviour, protocols and messages of communication.

2.1 Device Integration

The **BLE** (Bluetooth Low Energy) protocol (Bluetooth SIG, 2021) is the most commonly adopted standard communication protocol for phone connectable wearables and it is an optimized version of Bluetooth, with focus on efficiency in energy consumption. It specifies different layers for communication between BLE devices that ease processes such as advertising, scanning and connecting. Within the BLE context, a *service* is one or more attributes that specify a general functionality of a device (which can have many). A *characteristic* is a part of that service and defines a specific information provided within that service. Those services and characteristics are denominated by a standard *UUID* (Universally Unique Identifier), as depicted in Fig. 1, (e.g., if a device advertises the *UUID* specific for heart rate "*0x180D*", other devices may access that information knowing it includes a heart rate measurement).

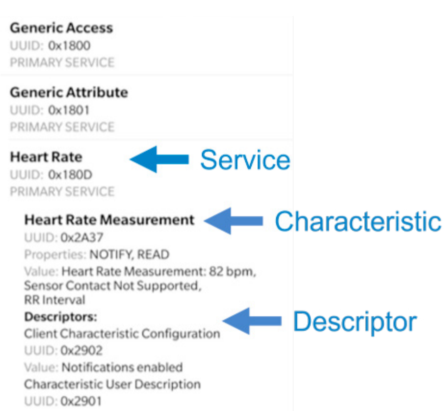

Fig. 1. Attributes of a standard device.

A *descriptor* can be used to manage the communication, showing if notifications or indications are enabled.

Within Citizen Hub, and in case devices are **compliant** with the BLE standards for *UUID*, integration is a relatively simple process. If not, and since many devices output more than one type of data and have multiple services and characteristics, it can be very time consuming to try to understand what values correspond to what measures, or even understand what the device really measures at all. An example is provided in Fig. 2, where services and characteristics do not follow the standard and the provided data is, at a first glance, incomprehensible. To overcome this, reverse-engineering processes may be needed to understand how the device works and how to effectively integrate it.

Fig. 2. Attributes of a non-standard device.

2.2 Communication

Once clarified how the device provides information and what the information means, communication must be established. Within Citizen Hub, a continuously running service is used to create and manage specific **agents** that deal with each connection. These agents contain device information, features, protocols and any additional algorithms to filter and process the device data. Each agent lasts the same time as corresponding connection and the objective is to ***establish a bridge of data between the device and the hub*** (Fig. 3).

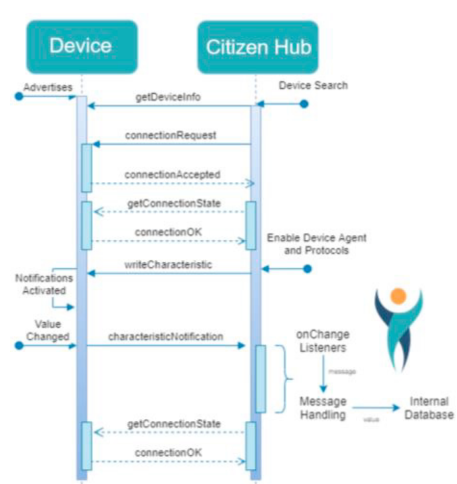

Fig. 3. Communication between Citizen Hub and devices (Seixas-Lopes *et al.*, 2022).

Initially, the Citizen Hub searches for available devices and establishes a connection. After that, the device notifies whenever new data is collected and sends the information. Citizen Hub receives and processes the message and stores the result internally.

To ensure interoperability with several platforms and systems, data is structured to be compliant with FHIR (Fast Healthcare Interoperability Resources) (HL7, 2021), a standard for health care data exchange that aims to structure and simplify interoperability. In this type of data structure, Citizen Hub defines each measurement as an **Observation**. The data provided in this Observation is bounded to a specific timeframe (i.e. when the measurement occurred), to a context (to further analyse the validity of the data) and is always associated with a standard unit (defined by a standard code within a mentioned terminology system), so other systems are able to identify and process the data provided.

2.3 IoT Architecture

The **IoT** is a term used to describe the emerging Internet-based information service architectures (Weber, 2009) that seek to connect everything to the Internet. The adopted IoT architecture follows the most common 3-layer approach, which consists on a perception layer, a network layer and an application layer (Wu *et al.*, 2010), and expands it considering the different functionalities and modules necessary for the implementation of the Citizen Hub application.

To collect and process data effectively, five specific architecture layers were envisioned for Citizen Hub, which connect to other two layers to acquire and facilitate data (Fig. 4).

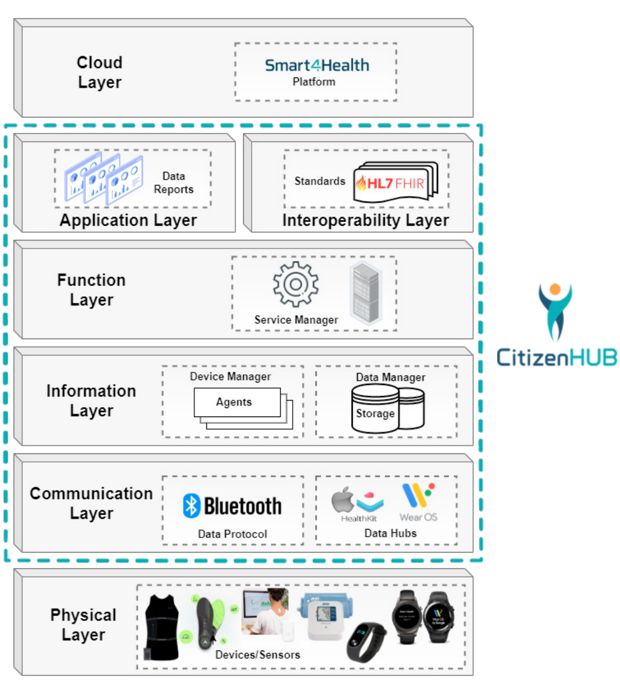

Fig. 4. Citizen Hub IoT Architecture.

The lower layers follow an ETL (Extract, Transform, Load) data ingestion approach (Meehan and Zdonik, 2017) and the upper layers are designed for user interaction, compatibility, interoperability and services/functionalities. This architecture was developed considering the gained experience, in previous implementations, of IoT methodologies and tools for previous projects in IoT data contexts, such as (Agostinho et al., 2019). Another important aspect, considered since the beginning of the development, were industry standard guidelines such as the Continua Design Guidelines (PCHA, 2019) to ensure compatibility with widely adopted open standards and interoperability with existing personal connected health solutions.

An overview of the architecture is provided in Fig. 4 and a brief explanation of each layer follows.

Physical Layer - The physical layer encompasses the various devices/wearables that were integrated and successfully communicate with the application. These devices are the data sources of the architecture.

Communication Layer - Handles communication with the data sources from the physical layer. It supports the different standard communication protocols, performs communication related to requests from upper layers and forwards incoming data to the information layer.

Information Layer - Processes the incoming data from the lower layers to make it usable. The Device Manager contains the data models and properties of the connected devices, which are handled with agents. The Data Manager uses protocols to transform the information and save it into internal storage.

Function Layer - The function layer represents the remaining backend work after the data is consolidated. The Service Manager contains continuous services that handle the general operations of the application, managing workloads and the backstage for application layer tasks.

Application Layer - This layer holds the different services and functionalities that are provided directly to the user through the interaction with the interface. Includes dashboards for configuration, visualization, integration and any supported analysis of data and other services, provided by the work of other layers or third-party applications.

Interoperability Layer - Allows communication with external systems through standards and dedicated connectors. This allows for an easy adaption, integration and communication of data. An example of a known standard is FHIR, that enables a quick adoption within the healthcare industry. Citizen Hub uses these standards to communicate with the cloud layer through a dedicated connector that uses the Smart4Health SDK (Software Development Kit).

Cloud Layer - This layer represents cloud infrastructures that are interoperable, such as the Smart4Health platform which is the recipient of the information selected by the user and provides access to the project services and functionalities. Due to this envision interoperability, other cloud layers from different project have been tested, with successful results.

3. ADAPTIVE WORK-LIFE BALANCE

With data being effectively collected and stored, it can be then processed to draw insightful conclusions when presented to the user. Citizen Hub provides two different settings for the collection of data: ***MyWork*** and ***MyTime***. These settings were designed to evaluate a work-life balance that is dynamically adjusted with every new piece of data that is collected.

3.1 MyWork

In ***MyWork***, data is collected in a work environment, whether it is in an office, a factory or any other physical space, the goal is to dynamically adjust parameters with the data that is being collected every day. In a first stage, data will be collected and assessed within a broad spectrum, considering contextual parameters (for validity) and comparing with generic thresholds for average levels of indicators (i.e., normal levels for blood pressure and heart rate, recommended daily amount of steps, etc.).

After collecting enough data, goals adjust, with a very moderate approach, to stimulate progress. The progress achieved itself serves as a measure to define how further progress is proposed to the user. Along with this, if the user chooses to share its data, data from co-workers and other people with similar work settings serve also as a measure of progress or comparison.

In addition to this, a healthy approach to the work setting must be complemented with other activities and lectures, that can provide information about occupational health and workplace safety and prevention, with the objective of steering users in the right direction and ensure metrics are achieved within healthy parameters.

For the application to correctly tag activity and measurements to this setting, the user previously defines his work schedule within the application settings (Fig. 5). Outside that defined period, data is disregarded from the conclusions/insights related to this setting.

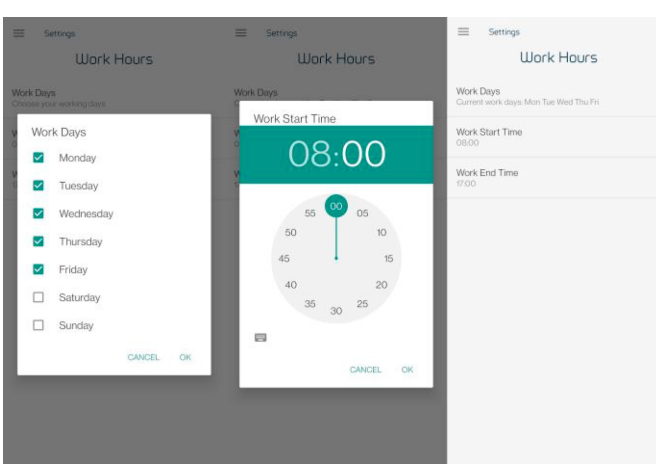

Fig. 5. Work hours settings in Citizen Hub.

3.2 MyTime

Outside the previously set period, the application considers the ***MyTime*** setting. A setting for daily routine and tasks, leisure, travel, fitness, where the user is subject to a larger variety of activities and, therefore, can draw different conclusions from the ones related to the work setting.

Some indicators are presented in Table 1. Most of them can be used in both settings, but an approach was designed with only some for each, considering the different possible conclusions that can be achieved for each setting. Also, some of the indicators can only be considered if the correspondent data is correctly collected using devices compatible with the application or the user inputs that information on a regular basis.

Table 1. MyWork/MyTime indicators.

	MyWork	*MyTime*
Steps	✓	✓
Calories	✓	✓
Distance Walked	×	✓
Avg. Heart Rate	✓	✓
Sitting Time	✓	✓
Standing Time	✓	✓
Sitting Posture	✓	×
Blood Pressure	✓	✓
Respiration Rate	✓	✓
Mental Fatigue	✓	×
Physical Fatigue	✓	×
Activity Time (Sports)	×	✓
Air Quality	✓	×
Noise	✓	×
Time Slept	×	✓
Sleep Satisfaction	×	✓
Mood	✓	✓
Food Habits	×	✓

Similarly to *MyWork*, there is an initial approach to objectives that is further refined to target the individual, adapting his goals to his progress, encouraging to improve by small increments every day or every week, to solidify progress, creating habits that contribute to wellbeing.

To implement qualitative metrics such as sleep satisfaction and mental fatigue, and other indicators that need a direct answer from the user (instead of device data) such as mood and food habits, the approach is to simplify the interaction to be as effortlessly as possible (Fig. 6).

With indicators coming from activities that range from exercising to common daily household tasks, comparison to peers can be extrapolated to a larger group, in this case, the user's community.

Fig. 6 – Mood assessment.

3.3 Community Engagement

Exercise and an active lifestyle play a critical role in healthy aging, maintaining functional ability and preventing and managing chronic conditions such as cardiovascular diseases and musculoskeletal disorders (Stuart *et al.*, 2009). Also, inactivity is directly associated with an increased risk of morbidity, functional limitations, disability and mortality (Morey *et al.*, 2002). Despite the importance of an active life, there are low levels of activity, especially in older adults (Centers for Disease Control and Prevention (CDC), 2003), with some barriers being financial costs, general interest in the matter, availability of time, lack of safe and nearby settings and other social and personal variables (Rimmer, Wang and Smith, 2008).

Sense of community is considered an indicator of quality of life and it measures how individuals relate with each other and how beneficial is that relationship (Ross and Searle, 2019). An approach to wellbeing in a community-level environment means utilizing the supportive aspect of people's close relationships to engage in cooperative actions or healthy competitivity. The motivation of goals within communities, encourages people to seek and engage others to participate in a healthier lifestyle (Dai and Menhas, 2020).

From an implementation point-of-view, characterizing groups based on physiological parameters (age and gender), lifestyle habits (food, sleep and physical activity) and psychological state (anxiety and basic needs) allows to target and improve the effectiveness of intervention strategies to promote quality of life and wellbeing (Antunes *et al.*, 2020).

In *MyTime* and *MyWork*, both settings are viewed as communities, with *MyTime* potentially representing larger ones. With each work colleague, neighbour or friend to simultaneously participate and contributing with data, which can be anonymised to address privacy concerns, engagement is envisioned by using it to create comparisons, challenges and community activity programs, stimulating people to remain active and accomplish their goals in cooperation with their peers. This data, coming from different people with different characteristics, helps further improve the models and algorithms of progress, also allowing to establish links to external factors (such as the weather and social context) and define levels of confidence (associated with the calibration of devices and consistency or quality of information inserted by the user).

The user gets a clean and straightforward interface with graphical representation of the achieved progress, in each indicator, in relation to the expected goal or threshold. Additionally, it also provides a comparison with the user's community, progress towards community cooperation challenges and additional insights to help achieve a healthy and well-balanced life.

The way these communities are going to be build, defined and managed, will depend on what devices and indicators the user chooses, as well on the level of security and privacy defined (which determines how the user's data is processed and whether is considered in the community context).

3.4 Insights for Health and Wellbeing

Sedentary behaviour involves activities with very low energy expenditure, performed mainly in a sitting or supine position. With considerable work being done in offices, there is a proliferation of sedentary habits in the workplace. Despite that, often workers do not compensate those long sitting hours by sitting less in their leisure time or when traveling to and from work (Jans, Proper and Hildebrandt, 2007). And even in more physical demanding jobs, that not require sitting for long periods, often workers are exposed to injuries due to incorrect working posture, due to bending, twisting, overreaching and performing repetitive tasks which contribute to musculoskeletal disorders (MSD) (Zein *et al.*, 2015).

To overcome these types of issues and mitigate a sedentary behaviour, the *MyWork*/*MyTime* indicators are used to paint a clearer picture of a certain person's current physical condition, habits and lifestyle. The data is collected and processed to reach initial conclusions and set a starting line. With more data collected, insights are provided and short-term goals are presented back to the user to instigate progress. Community workshops, challenges and workplace training, play a significant role by guiding the users to effectively improve their habits and reach the defined objectives, beyond the achieved metrics.

Considering how healthy physical development occurs over time and the obstacles of everyday life, the goals and measure of progress are adaptative, considering the user's own development. The data collected from other members of the community and information from other activities also impacts the user's progression, acting as feedback in a closed feedback loop (Fig. 7).

The collected community data allows to analyse behaviour and social patterns concerning physical activity. Taking inspiration from social organisms in the natural world, such as bees and ants, this data can be utilized to create an efficient and effective system for engaging individuals into participating in coordinated community cooperation and work together to accomplish health goals.

This bio-inspired model incorporates machine learning and data analytics to dynamically adapt over time and translates into the algorithm that continuously consumes newly collected data and provides insights and progressively sets goals that stimulate the user's progress towards a balanced lifestyle. By combining data from both *MyWork* and *MyTime*, insights about work-life balance are drawn, empowering the user to make better decisions and further improve his quality of life.

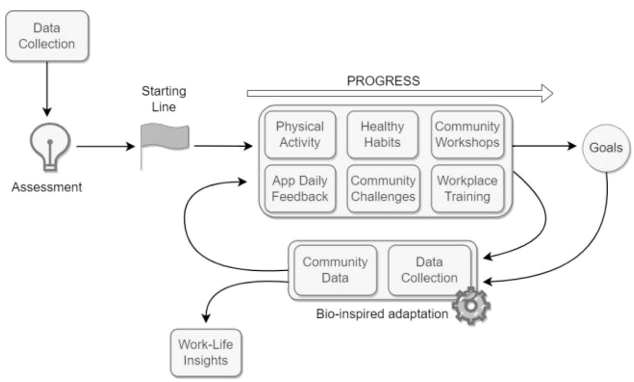

Fig. 7 – *MyTime*/*MyWork* progress.

4. TEST AND VALIDATION

4.1 Smart4Health Use Cases

Smart4Health (*Smart4Health*, 2022) is a European project that focus on the creation of a citizen-centered platform for the management of electronic health records, that allows users to handle and share data on their own terms.

The project is implementing eight different use cases for the development, implementation and validation of the Smart4Health platform functionalities (Marques *et al.*, 2019). To support the different contexts, six use design cases were defined that cover different user profiles and approaches to the use of the Smart4Health platform, with *MyTime* and *MyWork* being two of them. *MyTime* covers leisure, travel, fitness activities with an informative approach and focuses on the progress, cooperation with community and overall daily management. *MyWork* covers occupational health, safety training, injury prevention and overall work activities.

In one of the use cases, that aims to achieve a considerable amount of citizen involvement, Madeira's residents and tourists are encouraged to register in the Smart4Health platform and use Citizen Hub to collect data and upload it to the platform. The intention is to address users working, actively travelling and spending leisure time in the island of Madeira, with fitness, hiking and training cooperative challenges and activities. To achieve this, users are being provided with information regarding the project objectives and the expected impact in their wellbeing. If they are interested, they are instructed on how to register in the project's platform and how to use the Citizen Hub application, connect wearables and start collecting data.

4.2 Citizen Hub

Citizen Hub is a mobile solution where the user chooses how data is collected and stored. It emerged as a gateway application for the Smart4Health Health Data Platform and integrates wearables and medical devices, providing features that allow monitoring and managing habits that can greatly impact health and wellbeing.

Considering the broad target audience of the Smar4Health project, the Citizen Hub application provides a clean, simple, intuitive and straightforward interface (Fig. 8). The aim is to use the collected data to provide a short concise feedback to the user.

The set of fully integrated devices includes Xiaomi fitness bands, any Wear OS smartwatches, A&D blood pressure monitors, Upright posture sensors, Hexoskin smart shirts, Digitsole smart insoles, etc. Some of the metrics already integrated are steps, distance, pace, heart rate, back posture, calories, blood pressure, breathing rate and others.

Fig. 8 – Citizen Hub application user interface.

To complement the number of compatible devices, integrations with Google Wear OS and Apple HealthKit were developed. These act as data hubs and store user fitness and activity information, handling the data collection part. In these cases, Citizen Hub retrieves the information from these data hubs (in the case of Wear OS, through a dedicated Citizen Hub watch application (Fig. 9)) and processes it without the need of integrating each device that is compatible with either of the data hubs.

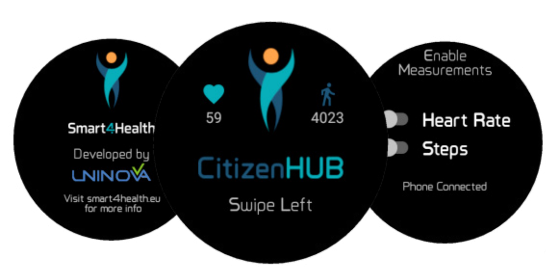

Fig. 9 – Citizen Hub Wear OS application user interface.

From a technical perspective, the implementation process for each device was time consuming considering the lack of compliance with the BLE standard in available Bluetooth devices, which required additional effort to identify the behaviour of the advertised features. The inconsistency of BLE devices, which communicate at short ranges and low speeds, also imposed the implementation of several reconnection methods to keep the devices synchronized with the application. Other mechanisms were also needed for preventing the phone's operating system to end services from the application while doing battery optimization, which varies for each phone manufacturer.

The Citizen Hub application is already available, successfully collecting data and displaying aggregated data. It presents daily summaries, daily activity reports (Fig. 10) and activity charts (Fig. 11). It is currently also being used by a group of caregiver workers within a Smart4Health use case, with the objective of getting a work setting dataset to test the bio-inspired model for the *MyWork/MyTime* features. Before rolling out a more extended version with the specification of goals and community challenges, this collected data will allow to validate (together with healthcare professionals and considering acceptable thresholds for each indicator) the adaptative algorithms and conclude the effectiveness of this methodology in creating healthy habits in both work and leisure settings, and the ability to provide a useful assessment about work-life balance.

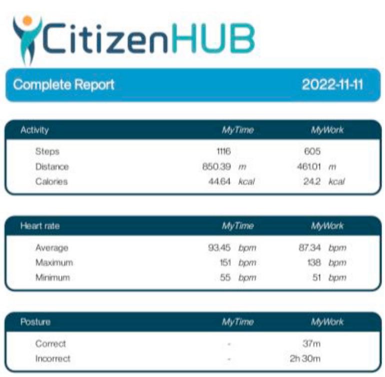

Fig. 10 – Daily Activity Report

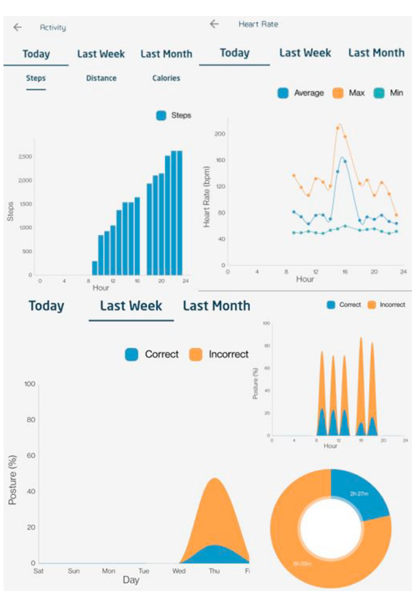

Fig. 11 – Activity Charts

Additionally, Citizen Hub features are being used for the pilot of the pilots initiative in the **Smart Bear** project (*Smart Bear Project*, 2022), with data being successfully integrated in the project cloud, verifying the cross-platform interoperability of this solution with platforms compliant with standardized data.

5. CONCLUSIONS AND FUTURE WORK

A prototype version of the Citizen Hub mobile application, with part of the functionalities described in this paper, is published and available to anyone with an android device, through the Google Play store. It successfully collects data from multiple devices that cover the indicators mentioned previously and provides configuration features for the user to customize how data is collected. That data is currently presented back to the user through a daily summary, daily reports and activity charts.

The *MyWork/MyTime* features empower the user with aggregated information that can be used to understand health or fitness related practices while working or during leisure time. A summary is already available when providing reports to the Smart4Health platform, while the community engagement functions are a work in progress, that are envisioned to be implemented and published within the main version of the Citizen Hub application in the near future.

To complement the technical implementation and further improve it, in a context of work-life balance and healthy lifestyle, user testing and feedback will be crucial to establish levels of confidence and understand how this methodology impacts the user and how beneficial it proves to be. Information from professional experts and known thresholds for health and fitness indicators will serve as basis to perform a comparison with the gathered feedback and the data collected through the application. The results of this analysis will contribute to further develop the bio-inspired model and its adaptative algorithms.

Future work also includes the compatibility with more devices, that aim to further increase/complement the type of information collected, updates to the application user interface and user experience, and the integration of other applications with Citizen Hub, to increase usage and be compatible with the routine of a larger number of users.

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