# IOM–Internet of Mobility: A Wearable Device for Outdoor Data Collection

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**Abstract.** Current technology allows the collection of data about cities by communities collaborating for the wellbeing of the city. The solution described in this paper is a wearable device ecosystem, called IOM (Internet of Mobility), consisting of a wearable device collecting environmental data through sensors to be visualized on a mobile or web platform. The paper focuses on the requirements analysis involving different types of target users and on the design of the wearable device.

**Keywords:** Wearable device · Smart city · Environmental data collection

## 1 Introduction

Emerging technologies, such as wireless sensor networks and internet-based mobile applications, have been reshaping our urban environments, making them smarter. According to the Digital Agenda for Europe smart cities are defined as places where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefits of its inhabitants and businesses. One of these enabling technological processes for smart cities is represented by the Wearable Technology, a rapidly evolving field expected to rocket dramatically in the next years. Although so far fitness and activity trackers have led the wearable device market, advances in material science, decreasing size and consumption of some sensors, collaborative platforms and social media, cloud computing, Internet of Thing (IoT) and Big Data science provide new potentialities and possibilities.

In this paper we present IOM, a wearable device prototype for gathering data about cities, processing and returning them to citizens in the form of customized maps and paths. The single user will acquire a deeper and wider knowledge about the city, feeling more comfortable to move in it and more embedded in the community, since his/her data will be used to build meaningful maps exploited by everyone. The core of this innovative service consists of raw, anonymous and open source data, accessible not


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only to the users but also to third parties. The latter would be able to carry out analysis on these data and probably bring to light valuable and hidden information exploitable to improve life conditions in the city as well as the city itself.

Thanks to the multidisciplinarity of the team, made of both engineers and designers with different expertise, both a functional prototype and a 3D printed prototype of the wearable device design have been produced. Furthermore, different issues, concerning user-centred design as well as hardware, software and business requirements, have been considered all along the process to propose a reasonable and practicable solution.

The paper is organized as follows: in Sect. 2 related work is reported; Sect. 3 reports requirements analysis. Section 4 describes the IOM solution, focusing on the wearable device prototype. Finally, Sect. 5 draws the conclusions.

## 2 Related Work

Wearable technology has emerged recently and several applications have been proposed. The fact that this technology can be worn and then taken everywhere, has favoured the emergence of a new phenomenon of participatory sensing or, as defined by Guo et al. [1], of Mobile Crowd Sensing (MCS), where everyday mobile devices form a network enabling people to gather, analyse and share local knowledge (Burke et al.) [2].

As pointed out by Delmastro et al. [9], "nowadays users not only represent the final utilizers of the technology, but they actively contribute to its evolution by assuming different roles: they act as humans, by sharing contents and experiences through social networks, and as virtual sensors, by moving freely in the environment with their sensing devices".

Of the same line is the work of Andrienko et al. [10]: they explain how the increasing market of wearable devices can provide new opportunities for applications that improve citizens quality of life, and show that the emerging phenomena of smart cities is giving rise to numerous challenges that can constitute a new interdisciplinary field of research.

aGrisu [3], Smart Citizen [4], and Netatmo [5] are examples of companies and projects producing wearable devices or services in part similar to our proposal, exploiting sensors to measure data about the environment. aGrisu [3] provides different products and apps including an environmental outdoor/indoor monitoring unit to collect data such as $CO_2$ level, VOC (Volatile Organic Compound), and Carbon Monoxide. Similar is the P-Sense wearable presented by Mendez et al. [6], for pollution monitoring and control of urban areas, allowing users and institutions to access such data for their benefit; however, they do not provide any real time interactive and customizable maps. Smart Citizen Kit [4] is an open-source environmental monitoring platform consisting of an arduino-compatible hardware, a data visualization web API, and a mobile app that has been used mostly for research purposes. It allows the visualization of measurements about CO, $NO_2$, light, humidity and temperature and sharing of data with other users of the community. Netatmo [5] offers a weather station. Although not in the field of wearable devices, it provides features and services close to IOM: a map with all the weather stations outdoor data is updated every few minutes, showing details about altitude, date and time of the last update/data measurement, temperature, humidity, pressure, and other useful data.

We considered also accessibility problems. Indeed, IOM exploits the algorithms of the MEP Project [7] to collect accessibility information in the city by exploiting mobile device sensors. Among the related projects, Wheelmap [8] is an online and worldwide map for finding and marking wheelchair accessible places: it enriches maps with information about accessibility, which is however collected manually, using a collaborative approach.

Table 1 summarizes the main characteristics (types of sensors, devices and platforms for data collection and visualization, etc.) of such proposals and compares them with our proposed system.

**Table 1.** Comparison of the characteristics of similar projects and products.

| Product | MEP-WEAR | Netatmo | Smart Citizen | aGrisu API | Wheelmap |
|---|---|---|---|---|---|
| Hardware | Mobile/wear | Fixed | Fixed | Mobile/wear | N/A |
| Web platform | Yes | Yes | Yes | No | Yes |
| Mobile app | Yes | Yes | Yes | Yes | Yes |
| Environmental data | Yes | Yes | Yes | Yes | No |
| Indoor/outdoor | Both | Indoor | Indoor | Both | N/A |
| GPS | Yes | No | No | Unknown | N/A |
| Bluetooth | Yes | No | No | Unknown | N/A |
| Humidity and temp | Yes | Yes | Yes | Yes | N/A |
| UV | Yes | No | No | Yes | N/A |
| Ambient light | Yes | No | Yes | Yes | N/A |
| Pollution | No | Yes | Yes | Yes | N/A |
| Sound/noise | Yes | Yes | Yes | No | N/A |
| Motion detection | Yes | No | No | Yes | N/A |
| Accessibility map | Yes | No | No | No | Yes |
| Cost | \$80–\$100 | \$190 | \$155 | N/A | Free |

## 3 Requirements Analysis

To identify the needs of the target users and collect their requirements, we carried on a survey that has been spread over the Web among very different customers' classes in terms of geographical provenience, culture, and age. Beside collecting data about users' profiles, questions tried to better understand users' attitudes and interest about the wearable technology sector. The survey allowed us to identify important and remarkable trends in relation to age, gender and customs of the possible final users.

The survey has been filled by a sample of two hundred and twenty people, with an age ranging from fifteen to sixty years. Figure 1 shows the age distribution among males and females.

On the basis of the results of the survey and users analysis, we identified six main personas/target users: the Movement Impeded, the Runner, the Walker, the Biker, the

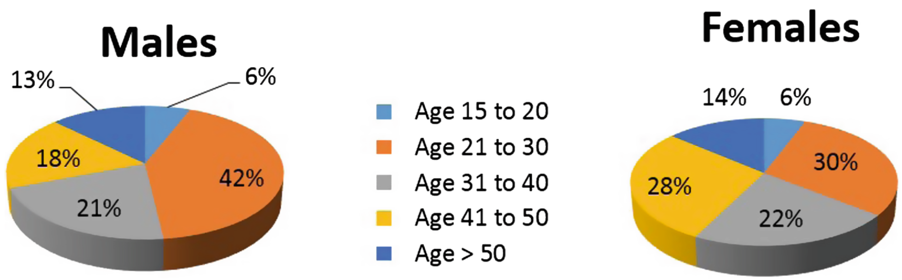


**Fig. 1.** Age distribution among males and females.

Exploiter (stakeholders interested to the collected data) and the External User (e.g., producers, advertisers, etc.). The performed analysis acquired a critical role directing the project activity, both at the level of hardware/software features specification and at the products' design.

As can be seen in Fig. 2, where one of the collected results is shown, the design of the device was another critical challenge considered in the survey since, as the set of sensors inside and the fact that has to be worn over the clothes, have influenced its final shape and material construction.

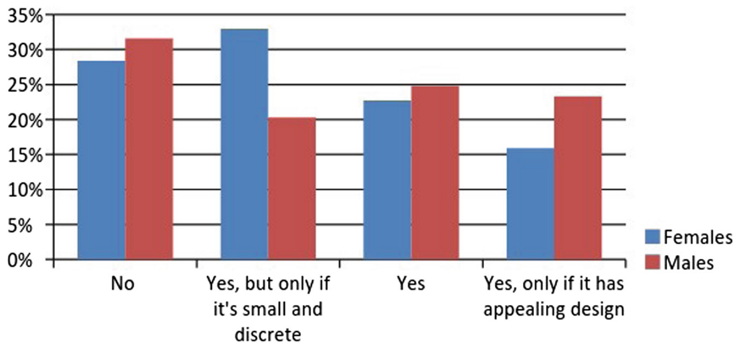


**Fig. 2.** Percentage of likeness of a possible wearable device.

Beside acquiring general information about the gender and the age of the sample, we tried to understand if users prefer to explore new areas or, on the contrary, they always choose the same paths. The former has come out to be the most chosen answer (60% against 40% for the latter) with no relevant difference with regard to the gender. With respect to the age it is noticeable that the only age band having a systematic preference towards the exploration of new areas is the highest one (older than fifty years).

Figure 3 shows the percentage of the preferred information that the users would like to know with the usage of the proposed system (multiple answers were allowed in this question), considering all the types of target users.

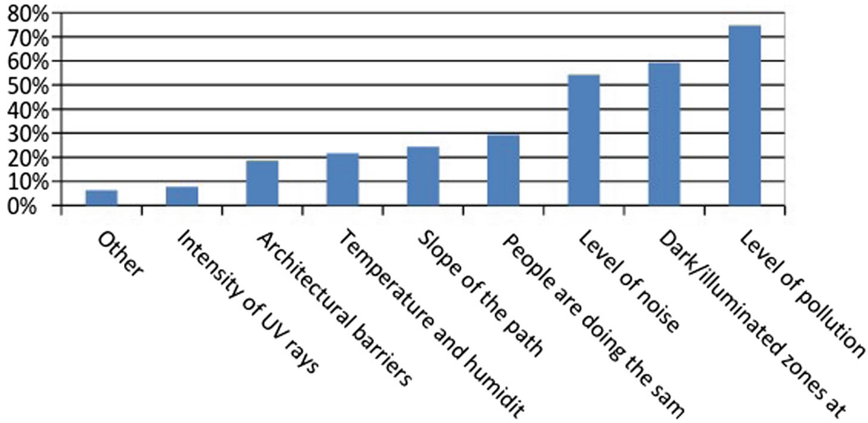


**Fig. 3.** Users' favorite information on personalized maps.

## 4 IOM Solution

The proposed solution is called IOM (Internet of Mobility), and consists of a wearable device that collects data in the city, and a mobile/Web platform for their visualization. The data collected by all the wearable devices are stored and processed to build maps based on these measurements (e.g., thedifferent average levels of humidity or of temperature in the city).

The IOM wearable device features different sensors, including temperature, humidity, UV, light and noise. Key points of the overall service are inter activity and customization: personalized maps can be built considering the main interests of the user and also personalized paths can be computed to offer to the user an experience fitted to his/her own needs of that particular moment. Thanks to an intuitive user interface of the application, provided both through a mobile app and a Web platform, the user would be able to set some filters in order to generate the appropriate map: for instance, a woman with a baby might be interested on a map reporting just UV and noise, while a runner would prefer to know pollution and humidity. The chosen solution allows to store and process anonymous data, therefore enabling everyone to access them, including external stakeholders which could use them to build new services. The IOM Mobile Application and the IOM Open Web Platform will work side by side with the wearable device designed in order to collect the data from the users that are moving around the city, allowing to have a better understanding of the condition of the city.

The hardware of the wearable device consists of different components including sensors, a subsystem for data handling and communication, and a power subsystem. Each sensor or module is connected to the main processor (an STM32F4xx micro-controller in our prototype) through different communication protocols such as UART, SPI, I2C, GPIO, etc. Figure 4 shows the overall schematic of the prototype. In the choice of which sensors to include we made a trade-off between the preferences expressed in the survey and the feasibility of the solution. Indeed, we excluded the level of pollution as directly measured data since to have a meaningful information

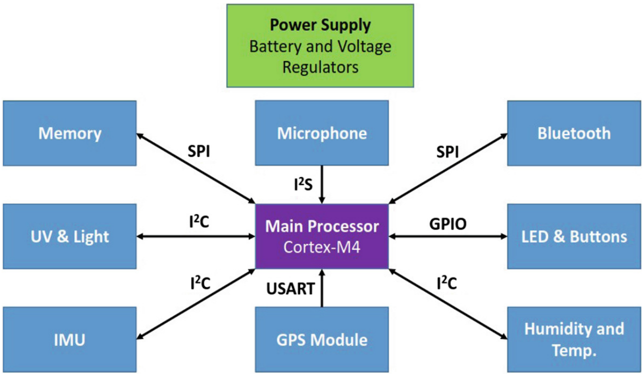


**Fig. 4.** Overall schematic of the prototype.

different sensors should be used and this would arise other issues on power consumption and size of the device.

Also the aesthetic of the wearable device was designed and built around the sensors board (Fig. 5). The device can be worn on clothes as a pin, in order to be always in contact with the environment, but can turn into a wristband if needed. We tried to satisfy the users' requirements emerged from the survey, i.e. a discrete and small device at the same time with an appealing design (Fig. 6).

**Fig. 5.** Different views of the IOM wearable device.

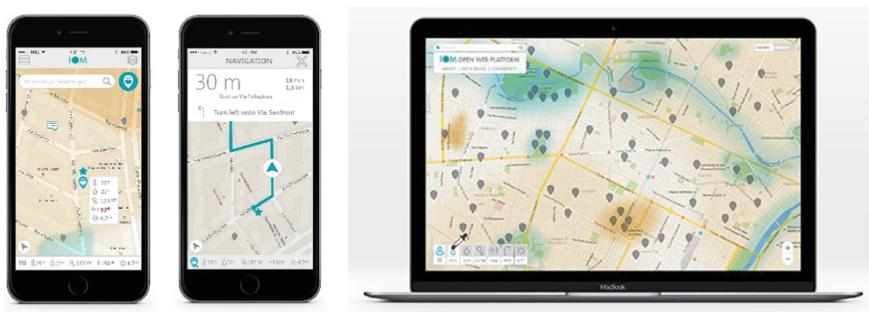

**Fig. 6.** Screenshot of the designed mobile application and web platform.

## 5 Conclusions and Future Work

IOM operates in the upcoming scenario of a new paradigm shift that the world is living in these days, in which IoT and connected devices are re-shaping our lives and cities, giving an idea of what the future might bring to us soon. We built and test a device prototype, in order to touch on real environmental data and we defined the electronic design of the miniaturized board taking into account the combination of the several requested functions, the power consumption constraints and the trade-off between hardware quality and costs.

We believe that our solution has high potential. Indeed, the heart of the concept is the open source cities data, and such valuable data could definitely give raise to strongly positive implications on the society development. In the future we may see prospects for the birth and improvement of products, services and business. For example, knowing which paths people are used to do, can be very interesting for planning the new shops, restaurant, public and private services; environmental data are instead exploitable by real estate companies, energy service provider or photovoltaic system provider. Moreover, since IOM is based on a dynamic and "living" network, where every citizen represents a moving measuring station, a scenario is forecast where it would be possible to have near real-time, continuous, widespread and detailed monitoring of our environment, not only cities but every place reachable by human beings.

A possible future service development can be related to a new IOM device that is equipped also with a heart rate sensor. Although we have already tested this kind of sensor on our prototype, we knowingly decided to not insert it in our solution; however, it could be very useful to identify correlations between heart monitoring and environmental parameters, especially for people with health problems.

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## References

1. Guo, B., Yu, Z., Zhou, X., Zhang, D.: From participatory sensing to mobile crowd sensing. In: IEEE Communication Magazine (2014)
2. Burke, J., Estrin, D., Hansen, M., Parker, A., Ramanathan, N., Reddy, S., Srivastava, M.B.: Participatory sensing. In: Center for Embedded Networked Sensing (CENS) (2006)
3. aGrisù – Environmental Monitoring. http://www.a-grisu.com
4. Smart Citizen – Open source technology for citizens political participation in smarter cities. https://smartcitizen.me/
5. Netatmo – Personal Weather Station. https://www.netatmo.com/

6. Mendez, D., Perez, A.J., Labrador, M.A., Marron, J.J.: P-Sense: a participatory sensing system for air pollution monitoring and control. In: IEEE Communication Magazine (2011)
7. Bobrova, N., Comai, S.: MEP-wear – wearable devices for data logging about cities. https://www.politesi.polimi.it/handle/10589/119262
8. Wheelmap – Map of Wheelchair Accessible Places. http://wheelmap.org/en/
9. Delmastro, F., Arnaboldi, V., Conti, M.: People-centric Computing and Communications in Smart Cities. In: IEEE Communication Magazine (2016)
10. Andrienko, G., Gunopulos, D., Ioannidis, Y., Kalogeraki, V., Katakis, I., Morik, K., Verscheure, O.: Mining urban data. Inf. Sys. (2016)