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How to control the Indoor Environmental Quality through the use of the Do-It-Yourself approach and new pervasive technologies

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Abstract

The article describes the results of the "Open-source Smart lamp" aimed at designing and developing a smart appliance that integrates a wireless communication system for building automation, following the maker movement philosophy. The device is able to get an overview of the potential of a nearable device equipped with a variety of sensors to broadcast digital data for the management and control of the Indoor Environmental Quality (IEQ) of the built environment. The Smart Lamp installed in a real office in order to test the reliability of the device in the management of the lighting and air quality levels.

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Keywords: Indoor Environmental Quality; Indoor Air Quality; Indoor Lighting Quality; Indoor Climate Quality, Internet of Things; DIY; Nearable; Building automation; enabling technologies; ZEB.

1. Introduction

In the past years, the actors of the building sector have been mainly involved in the design of new solutions to maximize the performance of technological systems for the definition of best solutions applicable to Zero Energy

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Building (ZEB) [1]. In most cases, the national and international bibliographical studies have focused their attention on the investigation of specific technical solutions to optimize building envelope strategies to reduce both cooling and heating energy consumptions respectively in summer and winter seasons, such as cool roofs [2-4], green roofs [5-8], dynamic windows [9] and so on; but sometimes planning important building retrofit strategies doesn't represent sustainable and sufficient solutions to achieve ZEB goals [10]. Today instead, the new frontiers are more and more involved in the development of integrated virtual environment [11, 12] and systems able to acquire, store and mine building data through the connection of Building Information Modeling (BIM) and the Internet of Things (IoT) [13]. While the BIM is the process related to the definition of digital representations of physical and functional characteristics of places [14], the IoT is essentially a network of connected and interconnected devices [15]. The spread of the IoT approach has allowed a proliferation of devices always connected in a communicating-actuating network, implemented following the "maker" movement and the Do-It-Yourself (DIY) philosophy, removing structural and technological obstacles [16]. Over the past years several shared projects and low-cost alternative technologies have appeared and developed, allowing end users to approach the electronics in a simple and fast way [17, 18, 19, 20, 21, 22]. The revolution of the DIY is the last in chronological order. After the agricultural and the industrial revolutions, the information age, the so-called Third Wave [23], draws upon the read/write functionality of the Internet and digitally-driven design/manufacture, to enable ordinary people to invent, design, make and, sometimes, sell goods and services [24]. Anybody at any location could carry out the principles of the DIY philosophy [25, 26, 27] through enabling technologies, for example Arduino or RaspberryPI.

The extreme flexibility of the technologies cited before allows their applications in different fields, like the Indoor Environmental Quality (IEQ) and energy consumption monitoring. As it is well known, the IEQ is a holistic concept including Indoor Air Quality (IAQ), Indoor Lighting Quality (ILQ) and indoor Acoustic comfort [28, 29, 30], besides the Indoor Climate Quality (ICQ). In addition these technologies could be fitted in common objects, transforming it in intelligent devices: in this sense the term "nearable object" (or nearable technology), used for the first time in 2014 as part of a marketing campaign, is now used to uniquely identify the idea of smart objects that can be equipped with a variety of sensors and can work as transmitters to broadcast digital data.

In the present article, the DIY approach has been applied to two nearable devices for the management of the IEQ and the related energy consumption. The ICQ, IAQ and ILQ are considered in the following scenarios. The devices were made using low-cost sensors, available on the market, wireless (IR and ZigBee) communication systems based on a LED IR and a XBee S2 communication modules, respectively. A 3D printer has been used for the implementation of the case. It implements Fused Deposition Modeling (FDM) technology [31] and uses polylactide (PLA) for printing. The PLA [32] is one of the most eco-friendly 3D printing materials available; it is made from annually renewable resources (corn-starch) and requires less energy to process than traditional (petroleum-based) plastics.

2. Application scenarios, hardware and software

2.1. Application scenarios

As evidence of the ability to apply and to adapt a nearable to the specific requirements by following the DIY approach, two different scenarios are considered corresponding to two different prototypes of a desk lamp, applied to the same case study aimed at optimizing different aspects of the IEQ. The former (Fig. 1a) in which the nearable tool is implemented and applied so as to optimize the ICQ. The latter (Fig. 1b) in which it is updated to optimize the IAQ and ILQ.