



Project Number: 644902

Project Acronym: LUMENTILE

Project title: LUMinous Electronic TILE

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Duration of the Project: 38 Months

Project final publishable report

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Project website address: <https://www.lumentile-project.eu/>

Dissemination level

PU	Public	<input checked="" type="checkbox"/>
PP	Restricted to other programme participants (including the Commission Services)	<input type="checkbox"/>
RE	Restricted to a group specified by the consortium (including the Commission Services)	<input type="checkbox"/>
CO	Confidential, only for members of the consortium (including the Commission Services)	<input type="checkbox"/>

SECTION 1

Summary of the context and overall objectives of the Project

LUMENTILE is a three-year, €3 million project funded by the European Commission under the Horizon 2020 research frame program. LUMENTILE has been focused on developing a disruptive new construction element to be used by designers and architects: a *ceramic luminous sensorized electronic tile*. Each tile will be made of ceramic with embedded electronic circuits and semiconductor high-efficiency LED light sources and will have the capability of changing color at the will of the user. The luminous FLOOR/WAL tiles can be installed like *normal tiles* by using a dry installation process, typically used in technical floating pavements, and can be deployed in private houses, public spaces, indoor or outdoor installations, for architectural design projects. In the case of VIDEO TILE, each luminous tile can also be used as a single pixel for giant video installations (e.g.: tiles with 30cm x 30cm size, with 16 independent pixels of 7.5cm x 7.5cm size can make a video of 60m x 48m size, with 800 x 640 = 0.5Mpixel resolution, for permanent installations on building facades without need for further specific maintenance).

The luminous tiles will be installed using a specially developed electrical interconnection and retaining system, so that all the tiles are electrically connected to each other and can exchange information. The luminous and electronic tiles are equipped with sensors (contactless gesture sensors for the wall tiles; pressure sensors for the floor tiles to detect people walking onto them) and constitute a network of interconnected smart-devices, that are ready for application in smart-city and smart-building environments.



Figure 1 Render of interactive luminous path at an airport application

LUMENTILE envisages designers and architects exploiting the intrinsic ability of the device to display lights, colors and images for both exterior and interior design and lighting. Not only could the tiles be used in shopping malls, airports and skyscrapers, but also for simple household illumination, where ambitious color and video effects would be replaced by a focus on luminous efficiency and ease of installation. Tiles are equipped with embedded sensors, for example a *pressure sensor capable of detecting the presence of person* standing or walking on a floor tile. In this way, the 'smart floor panels' can recognize when an elderly user is no longer standing or perhaps has fallen, or in security situations where a floor will be sensitive to intruders, or in shopping centers where a 'dynamic luminous path' can be created to direct shoppers to a particular store or defining "hot spot" for retailers (where people stay more time in front of specific place).



Figure 2 Application for personalized, luminous path guiding, and also security monitoring in an airport

Prototype of luminous tiles have been constructed and used in 3 demonstrators of large size, installed in selected public spaces to disseminate the novelty of the LUMENTILE products and reach potential customers and end-users.



Figure 3 Render of interior design application in a hotel lobby

Conclusions for the Project

The LUMENTILE Project has reached its termination (30 April 2018, total duration 38 months).

The technological and economic impact of the Project results is high, and it is highly likely that the developed technology will lead in the early future to a commercial exploitation of the LUMENTILE products. Participants of LUMENTILE are now in the process of completing the IPR definition, and setting up a spin-off Company that will commercially exploit the results obtained in the Project.

The scientific development of the Project was aimed at achieving the Demonstration objectives. Rather than groundbreaking "Science & Technology" development, LUMENTILE aimed at obtaining the best solutions from state-of-the-art knowledge from different fields and disciplines, putting into force a real interdisciplinary effort and a cross-fertilization of know-how and competences among the Participants.

The dissemination of the Project's results has found its peak in the exhibition of two fixed Demonstrators during the Milan Design Week, and in particular the Fuorisalone events (Milan, April 2018). The Demonstrators raised vivid interest in the public and in stakeholders, and gave a precious and valued feedback in terms of the assessment of the technical approaches chosen for the LUMENTILE prototypes. A third fixed demonstrator has been installed (and will remain in place for a field-test of 12 months duration) in the sports arena of the Milan Assago Forum, at the end of July 2019.

SECTION 2

Work performed during the Project and main results, including exploitation and dissemination

The initial phase of a large Project like LUMENTILE is the most delicate because one, because it is when people of different background and cultures need to be aligned towards the main objectives. Nevertheless, intense cross-fertilization of the know-how, and a open mind towards the final application and the users' needs helped in generating the right specifications for the devices / products to be further developed.

The technical and engineering specifications for the LUMENTILE products have been defined by taking into great attention the needs of the end-users and of the interior designers or architects that will use and install the LUMENTILE products. An in-deep analysis of the construction market and potential final users' has been performed with the objective to define properly the right product for the right segment. The products need to meet and match the way of working and thinking of architects and designers; so *flexibility, modularity, customizable, and inconspicuousness* are some words that can well define what the above professionals are looking for.

3 products have been defined for specific targeted markets. Floor, Wall and Video Wall LUMENTILE products are for private sectors: Hotels, Retails, Congress centers, Airports is where this product can be installed and where the demand will be high.

During this phase, each single technological component was specified and a deep R&D phase started to answer properly to specification and requirements in different WPs addressed to single components: Optical System, Electronic System, Software and Tile communication protocols, Ceramic and other crucial subcomponents such as Connectile box, Bus and other electrical subcomponents. In a more schematic way we can divide the LUMENTILE in 2 parts: the **Luminous tile** and the **Connectile system**.

THE LUMINOUS TILE

The LAYERS

Top Layer

The top layer is the element of the LUENTILE that is in contact with the outer world (and possibly harsh environment, i.e., direct sunlight, rain, freezing, pressure, mechanical shocks) and the users. Different materials have been considered: translucent ceramic, glass and polycarbonate have been selected as potential materials. Research and development started from the laboratory.

Bottom Layer

The bottom ceramic layer has the goal of giving mechanical strength to the tile and of embedding the driving and control electronic circuits.

The ELECTRONIC and OPTICAL HARDWARE (Intermediate, "smart" layer)

The electronic "smart" core of the LUMENTILE includes large-area electronic circuits and high brightness discrete LEDs, of red, green and blue color, that are capable of generating any possible color. The electronic layer also includes the sensors for detecting people walking onto the tiles (for floor applications) and detecting users' gesture (for wall tiles).

The point-like light emission of the numerous, tiny RGB LEDs is transformed into a uniformly distributed light emission over the whole top surface of the tiles by means of suitably designed and manufactured light-guiding and light-diffusing layers.

For the VIDEO tiles, a new technology has been used to print the large-area electronic circuits for the RGB LEDs directly on a low-cost and flexible substrate such as PET (i.e., the same material that makes plastic bottles and acetate slides for overhead projectors).

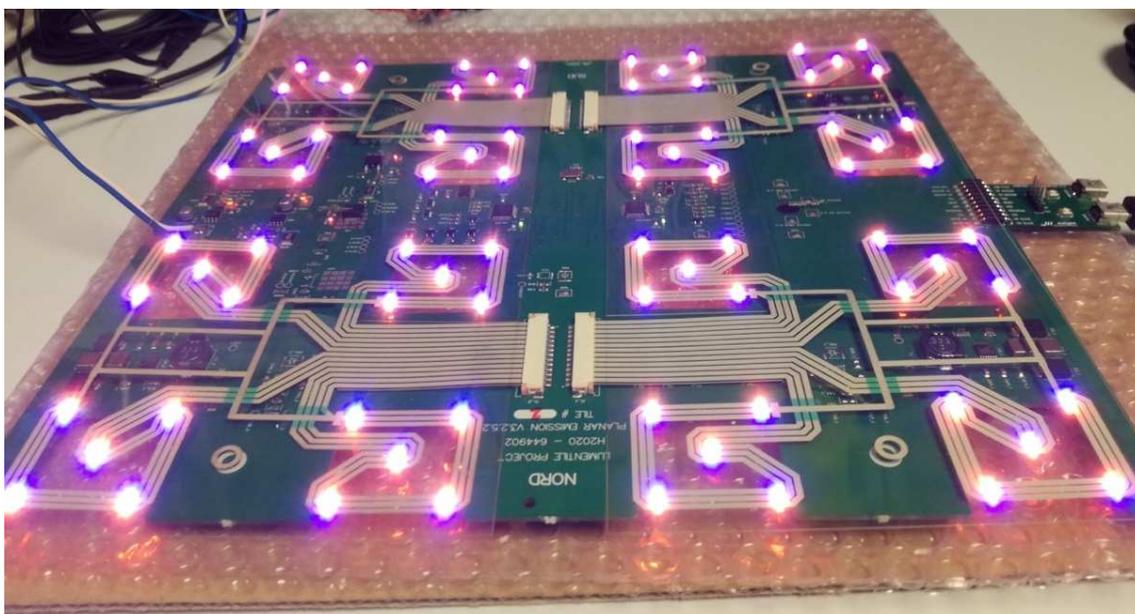


Figure 4 Luminous PET foil with RGB LEDs, realized using ink-printing technology onto a flexible substrate

The SENSORS

The specific type of sensors depends on the considered application. *Pressure sensors* that use traditional sensors or newly developed optical sensors are used in the FLOOR application to detect persons walking on the tile floor. Contactless *gesture sensors* are used in the WALL application to detect the proximity of the user and the movements of his/her hands over the tile surface. Both types of sensors can be used to implement interactivity of the installed tile cover.

For example, in the demo applications developed during the FuoriSalone international event, held in April 2018 in Milan, the pressure sensors for the FLOOR application have been used to generate a smart interactivity in an open square, where people walking onto the tiles made them change color, intensity, and the

volume of an audio soundtrack. These sensors have also been used to estimate the total number of people that walked onto the floor during the exhibition days.

The gesture sensors have been used in the WALL application to realize a giant Tetris™ video game, where the players could interact with the falling blocks and move them by just waving their hands in close vicinity of the tiles.

The SOFTWARE

The software is at the core of the functionalities featured by the three products delivered in the project. The software code developed to run the different products can be distinguished into **firmware** and **application software**. The **firmware** runs on top of the micro-controller equipping each tile, while the **application software** runs on an external control station that configures, coordinates and controls the set of installed tiles.

According to the requirements of the different applications, dedicated software stacks have been designed, implemented, tested and validated. FLOOR and WALL applications are based on the so-called Low Data-Rate (LDR) architecture. Key goals of the LDR architecture is the support of any cover layout, automatic configuration of the cover, arbitrary rotation of the tiles (when they are installed), real-time fault tolerance to deal with broken tiles or links, and interactivity management through sensors. The LDR application does not address a high refresh rate of the tile's colors. The LDR application has been implemented by designing a tile-to-tile communication protocol that allows the tiles to exchange information and to forward commands. The communication between the external control station and the tiles is enabled by dedicated hardware components called "control points". The software running on the control station supports an arbitrary number of control points. Since each control point is responsible for the control of a sub-set of tiles in the cover, this means that **arbitrary scalability is allowed** by increasing the number of control points.

The protocol allows also the collection of sensory information from the tiles. Part of the protocol has been implemented as firmware that runs on top of the micro-controller within each tile, while part of the protocol runs on the control station.

The Lumentile APP

A user-friendly Android App has been developed, with the goal of exchanging data with the wall/floor tile cover. It can be used to change the appearance and color of the installation, and to show in real-time traces of the different people walking onto the tiles.

OUTSIDE THE LUMINOUS TILE: THE CONNECTILE SYSTEM

The tiles are installed by placing them into a suitably designed plastic holder/socket, called the ConnectTile, each hosting and keeping into place four corners of four adjacent tiles. The ConnectTile not only provides mechanical stability to the floor/wall cover, but it also has embedded electrical contacts that are used to bring to each tile the electrical power, and to allow the tile communicate digital data between each other (for example: information about the color configuration of each tile, or data collected by the sensors embedded into the tiles).

After several designing, 3D printings, product testing, mouldings-based tests and at least 5 different prototypes, a final moulded ConnecTile device has been tested, produced to be mounted in all the demonstrators realized during the Project.

The ConnecTile system is capable of providing different levels of protection, from IP64 to IP67.

Communication and Dissemination

All the information about the LUMENTILE Project as well as media materials are available on the project website: www.lumentile-project.eu

The following LUMENTILE accounts have been created on different media and social channels:

Twitter: <https://twitter.com/lumentileeu>

LinkedIn: <https://www.linkedin.com/company/lumentile-project/>

Facebook: <https://www.facebook.com/lumentile/>

Instagram: <https://www.instagram.com/lumentile>

LUMENTILE demonstrators and products have been showcased in many different international Trade-Fairs and Exhibition, like the prestigious CES 2018 (Consumer Electronic Show) in Las Vegas.

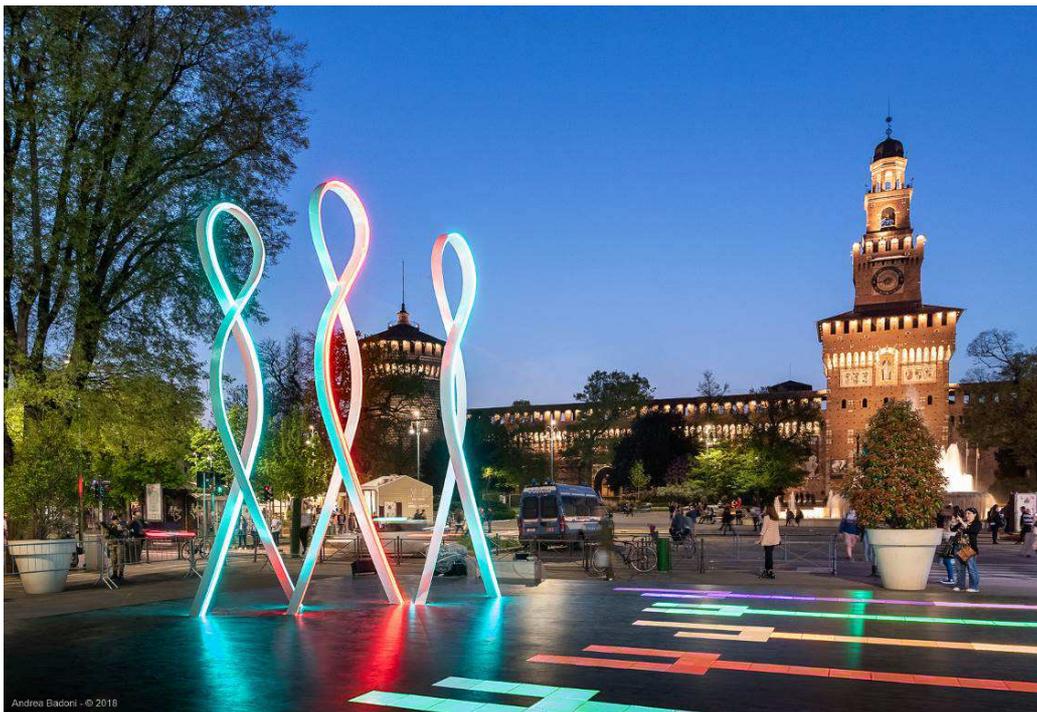


Figure 5 Night view of the installation of LUMENTILE floor Demonstrator at Fuorisalone, Milan (April 2018)

LUMENTILE demonstrators have been widely showcased in Milan during the Fuorisalone Design Week in April 2018, that is a flourishing event distributed all over the city, which turns into a dazzling and exciting en-plain-air event.

LUMENTILE participated in the Fuorisalone 2018 with two fixed demonstrators installations.

A LUMENTILE interactive wall representing a giant Tetris video game has been installed in Milano Lambrate design district.

A LUMENTILE floor installation was showcased in the central Piazza Castello in Milan, where more than 80,000 people could interact and play with the luminous interactive tiles.

LUM;ENTILE also organized two special events during the Fuorisalone in Milan: a Workshop on Smart-City emerging technologies, and a Round-table on new trends in illumination and lighting using new technologies.



Figure 6 Night user experience of people with the LUMENTILE Floor fixed Demonstrator during the Fuorisalone, Milan (April 2018)

A Virtual Reality video was produced showing potential application of LUMENTILE to hotels airports and retail shops, realizing interactive luminous paths and other intriguing applications.

Intellectual Property Management and exploitation

The technologies developed by LUMENTILE have been protected through five international patents (PCT) and the logo and name LUMENTILE have been registered as trade marks (European Union Intellectual Property Office –EUIPO-, application no. 016266306).

The technologies and solution generated in LUMENTILE will be brought to the market through one of the following approaches: i) Licensing of the intellectual property to a third party; ii) Creation of a newco spin-off Company, founded and owned by some of the LUMENTILE Partners together with new subjects.

SECTION 3

Progress beyond the state of the art, and potential impact

Progress beyond the state-of-the-art has been achieved in the majority of the research areas targeted by the LUMENTILE Project and in the whole concept of the LUMENTILE system. The main achievements that demonstrated progress beyond the state-of-the-art are listed below.

- Translucent ceramic top layer.
- Large-area electronics for the smart control of LEDs and sensors, and for the management, on-board of each tile, of the communication of data to/from neighboring tiles.
- Embedded sensors for pressure (walking) and gesture detection, integrated into smart electronic tiles.
- ConnectTile: mechanical and electrical connection system for the LUMENTILE tiles
- Software and firmware for the management and control of the network of smart, luminous and sensorized tiles
- Photonic solutions for creating a uniform illumination on the top of the tiles, starting from point-like LED emitters.
- New products, including: the LDR Color WALL, the LDR Color FLOOR, the HDR Video tiles. The luminous and sensorized tile product and installation is perceived as a total novelty by the general public and by stakeholders, as revealed by the strong impact of the fixed demonstrators that have been developed. In this respect, the concept of a "new product" is to be interpreted really literally: the LUMENTILE LDR products go beyond existing technologies and existing products, being easily installable and rugged, and with the characteristics of a "building and construction" material element, and providing interactive experience with the luminous tile concept.
- New applications, ranging from interior design to public spaces, in the context of smart-city development. In this respect, the LUMENTILE Consortium will strongly push the applications that are visually described in the virtual reality video, namely: airports (with LDR FLOOR for interactive guidance and security, and LDR WALL for the creation of ambience and atmosphere), and retail (for brand recognition and innovation perception).

The next phase of this Project will be the industrialization in order to reach TRL9 and to start industrial production at a medium-large scale (expected goal within two years from the end of the Project: >10,000 sqm/yr production volume).