CERAMICS, ELECTRONICS, AND ARCHITECTURE

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ABSTRACT

In this paper, possibilities for incorporating electronic and optical devices in the field of ceramics are put forward with a view to promoting their application in new environments related to domotics and the smart design of spaces, for example for the handicapped, signage, or lighting.

This study takes the “Room Escape” project as a starting point, which was an exhibition space set up by ITC-Alicer in which some capacitive sensors were installed under the floor for detecting the position of visitors. This allowed a system to be created that converted the flooring of the space into a large game board, which challenged visitors to repeat different series of lights that lit up under their feet.

Based on this knowledge, the field of non-conventional ceramics applications has then further been addressed, presenting possibilities that currently exist or could become possible in the near future, illustrating these with practical examples as an introduction, in order to explain the physical principles on which the sensors and techniques used are based, as well as to explain the procedure for incorporating their functional elements, thus going beyond the limits of the available space and the energy autonomy of the different mechanisms presented.

1. INTRODUCTION

The exhibition space presented, called "Room escape", was set in the framework of Trans-hitos 09 "Networks", the exposition of architecture and interior design in ceramics organized by the Instituto de Tecnología Cerámica (ITC) through its Area for Design and Architecture, Alicer. The exhibition is organized to transmit new uses and functions of ceramics to architects, technical architects, decorators, interior designers, promoters, builders, manufacturers, and designers.

The space involved was characterized by proposing a game to its visitors in which they had to observe different series of lights that appeared under their feet when the initial sensor was activated.

In order to develop this mechanism, a system of tiles had to be created that could generate light signals to show the series of lights that were to be repeated, which, in turn, were capable of detecting the presence of visitors' feet when they were trying to repeat the proposed sequence.

2. DEVELOPMENT

2.1. Considerations.

The design process began by considering the following different aspects that needed to be taken into account for appropriate development:

2.1.1. The space.

- Ceramics were to be the main feature of the space, integrating floor and wall tiling, the support for the sensors and lighting, the input and output signals, and the explanation of the instructions for the game.
- The space was to create a sufficiently subdued atmosphere to allow the lights of the game to be distinguished.
- The space needed to allow multiple visitors to move around easily, and avoid crowding.
- There needed to be a concealed space in which the sensors, lighting, wiring, and controllers were lodged.

2.1.2. The mechanism of the game.

- Both sensors and lighting had to work without affecting the function of the flooring (no risk of tripping when moving around).
- The difficulty of the game had to be adapted to all types of visitors, independently of their age, training, or level of involvement in the game.

2.2. Solutions.

2.2.1. Structure of the space.

With respect to the structure of the space, a 4x4x4 metre cube shape was used, with two high grooves on parallel sides, which protected the inside from daylight and created a dark atmosphere that allowed the light signals emitted by the game to be seen.

Figure 1. Outside of the space.

This structure was set on a wooden framework, clad on the outside with white glazed porous ceramics and clad with grey wooden panels on the inside. In order to house all the sensors, lighting and wiring, the floor was raised and could be inspected at those points where the electronics needed to be accessed. To hide the computer and the control card, one of the side walls was provided with a hidden compartment in a false bottom, in order to have them at hand without the public being able to access them.

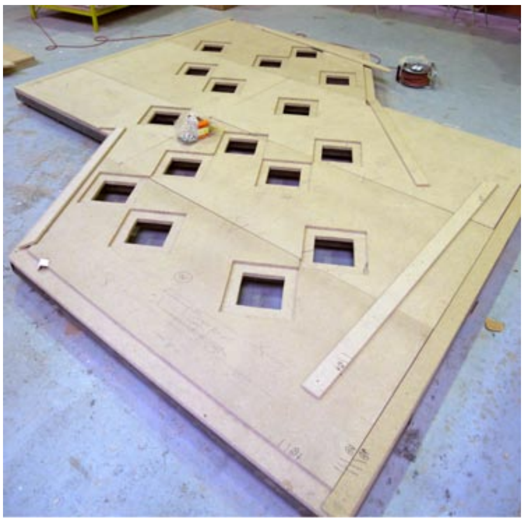

Figure 2. Raised flooring.

Figure 3. Hidden compartment.

On the outside of the space, several tiles were installed with red glass set in grooves made in the ceramics, which acted as signals to indicate the entrance and exit of the space. There was also an inkjet printed tile inside at the entrance, which displayed the rules and functioning of the game.

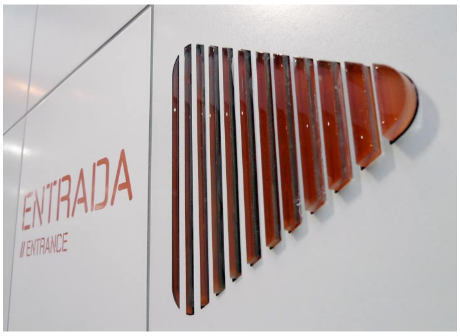

Figure 4. Signage.

Figure 5. Rules of the game.

A circular waterjet perforation was made in the floor tiles that acted as "game squares", into which a sanded glass ring was introduced that contained a circle of the same tile in the middle. There was, thus, a translucent ring through which the game's luminous signs could be viewed. The ceramic circle and the glass ring were adhered to each other and to the ceramic tile with epoxy resin, and they were grouted with grout paste. For the assembly to resist the weight of the visitors, a 6 mm-thick laminated glass square was joined to the back of the tile with silicone to prevent the centre ring from shifting.

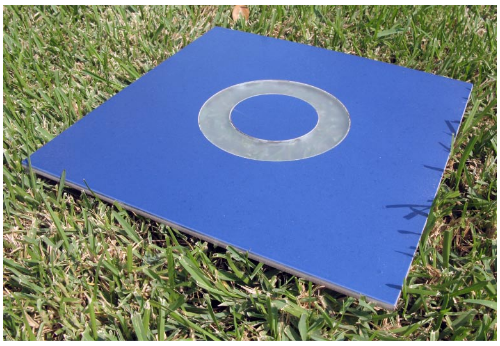

Figure 6. Tile with glass ring.

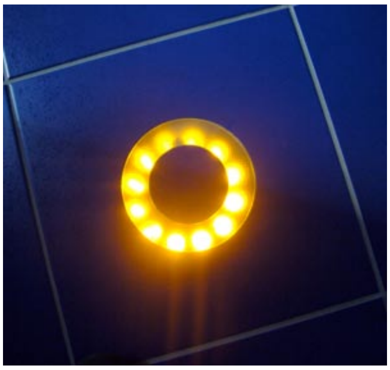

Figure 7. Lighted tile.

2.2.2. The game mechanism.

With regard to the game mechanism, the following solutions were adopted:

For the emission of light signs, a high-luminosity 12-LED ring, pre-set on a printed circuit, was chosen. A total of sixteen different-coloured rings were purchased (white, green, blue, and red).

To activate the game squares, a system had to be found that was capable of detecting players' feet through the ceramic tile without using mechanical buttons. This was a capacitive sensor, which worked by indicating a change of status based on the variation of the stimulus in an electric field. The capacitive sensors detect metal or non-metal objects by measuring the change in the capacitance, which depends on the dielectric constant of the material to be detected, its mass, size, and distance to the detector's sensitive surface.

The capacitive sensors are built based on an RC oscillator, whose best known application is impedance measurement. Due to the influence of the object to be detected and the change in capacitance, the amplification is increased by making the oscillator begin to oscillate. The exact point of this function can be adjusted with a potentiometer, which controls the oscillator feedback, enabling the distance for the action in certain materials to be adjusted. The oscillator output signal feeds another amplifier which, in turn, passes the signal on to the output phase.

When a conducting object approaches the active side of the sensor, the object acts like a condenser. If the approaching object is a poor conductor, such as a the player's foot, only a small change is produced in the dielectric constant and the increase in its capacitance is very small in comparison with the conducting materials, so that the distance of action needs to be calibrated with the potentiometer for the sensor to be capable of detecting a player's foot, which is insulated by footwear and the ceramic tile at the same time.

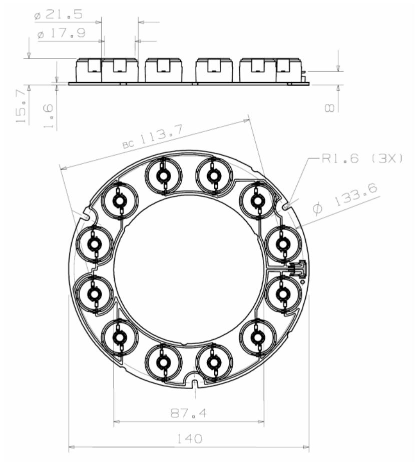

Figure 8. LED ring.

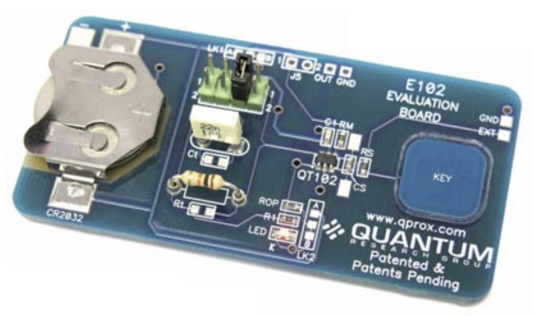

Figure 9. Capacitive sensor

The assembly diagram of the sensor system is shown in figure 10.

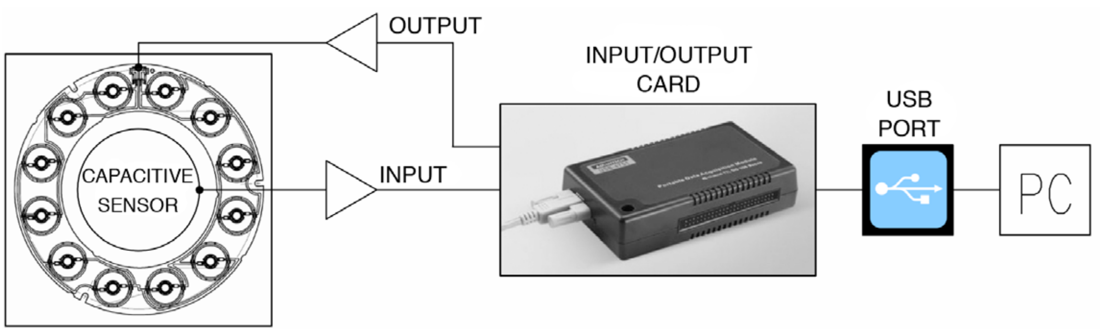

Figure 10. Assembly diagram.

Although only a LED ring and a capacitive sensor are shown in the diagram (the latter is placed in the centre of the former), there were sixteen pairs of LEDs and sensors in the actual assembly, which were connected to the input and output card that interpreted the output phase signal of the capacitive sensors as input, and handled the LED ring activations through its outputs.

This I/O Card was connected to the PC through the USB port, which contained a program that made the assembly work as an interactive game.

The working diagram of the "Room escape" program is shown below:

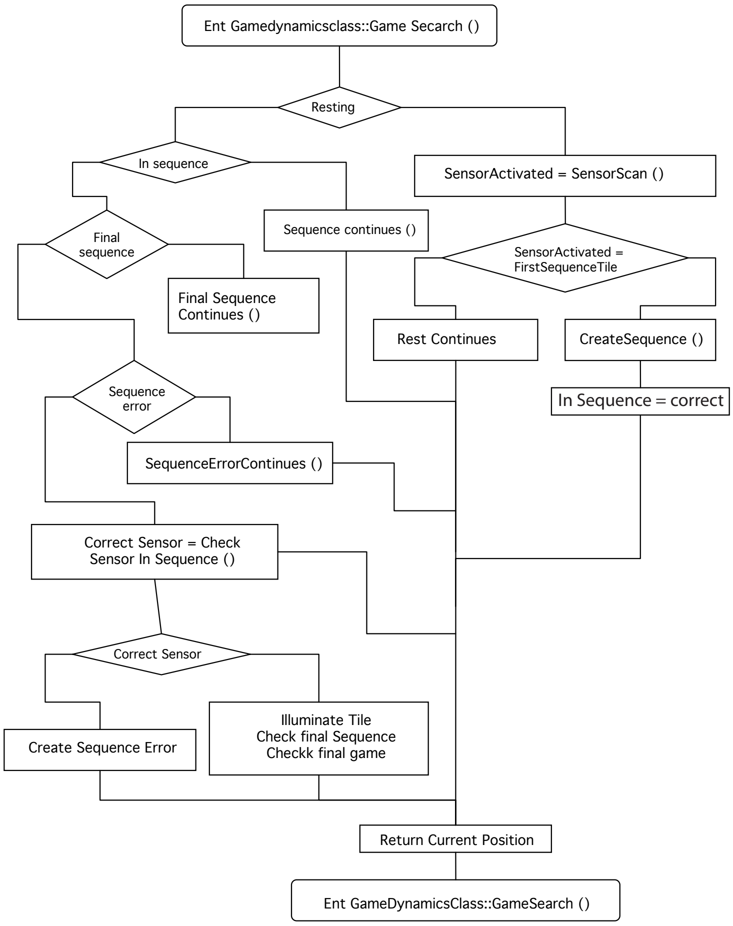

Figure 11.

The dynamics of the game begin when the player presses the initial square, which changes position in each game and can be recognised because it flashes while waiting for the game to start.

The first two game squares then light up successively; these can be any of the sixteen squares that make up the game, but they will always be close to each other. When the player has repeated this first series, the first level will have been passed and the program will go on to propose the next one to the player, in which there will be three squares whose activation order will need to be repeated. Finally, the game proposes a series of four squares one after the other, and if they are passed, the player will have reached the end of the game, which is represented by repeated flashing of all the squares at once.

All the luminous signs will be accompanied by their corresponding musical tone, reproduced by loudspeakers connected to the PC.

The following figures show the system of the game before and after it is installed in the "Room escape".

Figure 12. System before being installed.

Figure 13. System installed in the space.

3. REAL APPLICATION OF THE SYSTEM

We can find a possible real application of the system on a floor capable of detecting the position of people in a room and acting in consequence to the arising situations.

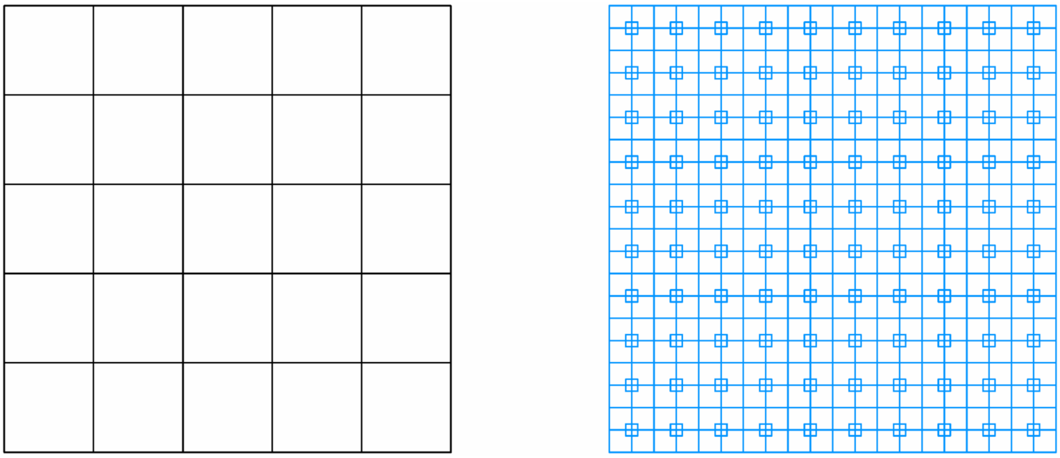

Figure 14. Floor with sensing surface.

If a multitude of capacitive sensors are arranged across the floor surface, different situations can be monitored:

- **Detection of paths**: by identifying the series of sensors that are activated by a person's feet when a person is walking, the person's path can be identified allowing the places where that person may be heading to be anticipated. This would make it possible for services like the opening and closing of doors on approach, lights being turned on or off, air conditioners being activated and deactivated, etc. to be installed. As well as being used to help the inhabitants of a house while they are at home, this application could protect the home from burglaries since it can be set up as a presence detection system when the house is unoccupied, while it can also store information on the path followed by an intruder in breaking and entering.

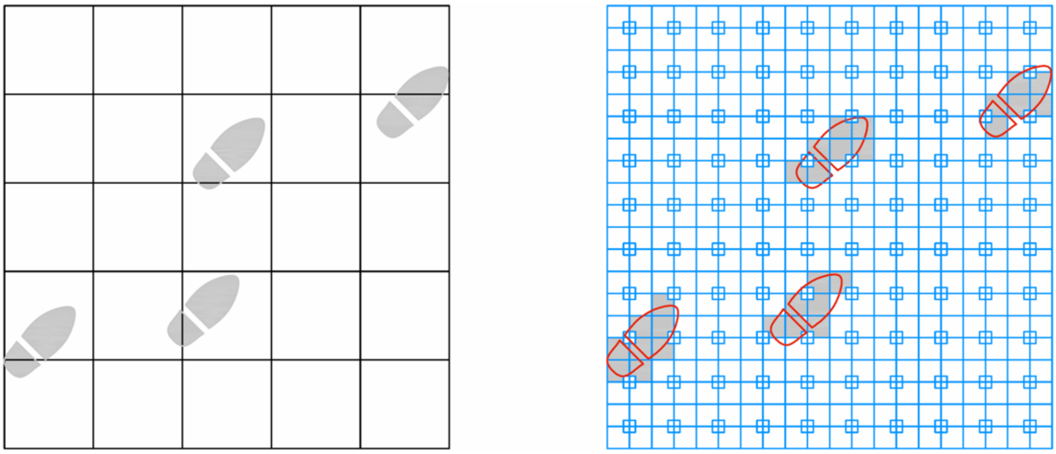

Figure 15. Detection of pathways.

- **Detection of falls**: by identifying the sensors that are activated when a person falls to the floor, a system can be created that triggers an alarm if there is an accidental fall.

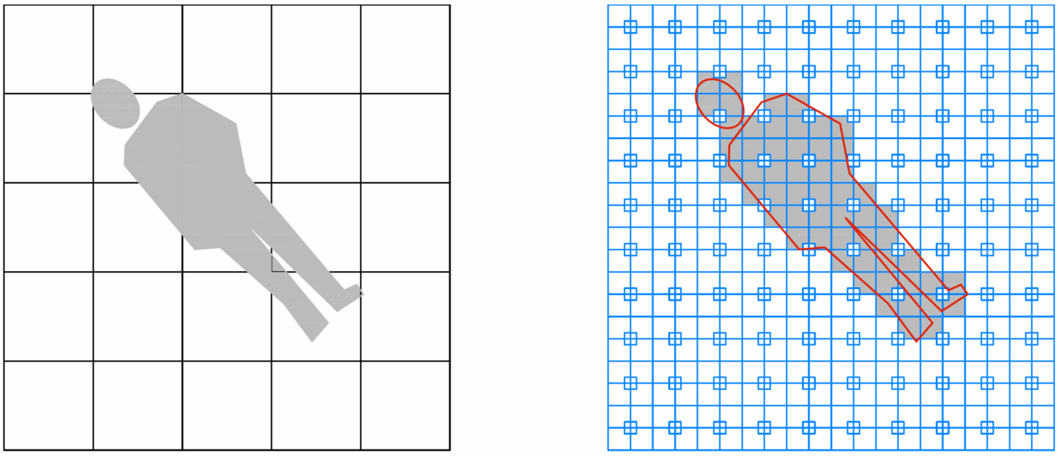

Figure 16. Detection of falls.

4. THE SYSTEM'S AUTONOMY

In the "Room escape" space, all the power and data transmission installations were made using electric wires, but there are more discreet types of installation that need no complex wiring across large surfaces.

- **Data transmission**: There are cordless systems that transmit sensor signals by radio at frequencies of 868 or 315 MHz with low energy consumption of about 50 μWs, at distances of 300m under the open sky and 30m inside in less than one thousandth of a second, entailing very low energy consumption.
- **Power**: There are many ways of using the small energy sources to be found in a building.
  - Movement: electric energy can be extracted by means of electrodynamic converters from any movement produced in a room, such as the opening and closing of doors, drawers, windows and blinds, the movement of office chairs, etc.
  - Rotation: generators can be installed that produce electric energy using the rotation of gas and water meter rotor blades.
  - Sunlight: the sunlight that enters a room can be used through small solar plaques placed in well-lit places.
  - Heat sources: electric energy can be drawn by means of peltier modules from minimum differences in temperature, like those found in a computer heat dissipater, a person's body heat (when sitting on a chair), air conditioning extractors, etc.
  - Vibration: the energy from any vibrating object can be used, such as a refrigerator compressor, a washing machine, or any machine with a motor.

By using these systems for data transmission and power, a cordless sensor system can be designed that "harvests" its own energy, thereby suppressing the installation and repair complexity involved in wiring large surface areas.

5. CONCLUSIONS

It may be concluded that incorporating capacitive sensors into ceramic tiles allows the flooring to be equipped with the capacity of "sensing" the presence of people who are walking on it, as well as of determining different situations in which these people may be involved in order to provide responses to these situations.

Depending on the place in which they need to be installed and the uses required of them, the best way to install these sensors involves adding power and data transmission systems to the sensors, thus suppressing the need to wire large surface areas, converting every sensing tile into an independent or "Stand alone" system, capable of providing its own energy and of transmitting the information from the sensors without requiring external power.

A building designed to accommodate these types of installations has the advantage of being readily constructed, because of the great flexibility in the floor installation layouts, since it is not necessary for these installations to be connected to any wiring. This allows such layouts to be independent of that of the wall installations, while facilitating subsequent changes in the room arrangement.

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