System monitoring feedback in cinemas and harvesting energy of the air conditioning condenser

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Abstract. Our article monitors the degree of emotional involvement of the audience in the action film in theaters by measuring the concentration of CO2. The software performs data processing obtained dispersion sensors and displays data during the film. The software will also trigger the start of the air conditioning condenser where we can get harvesting energy by installing a piezoelectric device. Useful energy can be recovered from various waste produced in cinema. The time lag between actions and changes in environmental systems determines that decisions made now will affect subsequent generations and the future of our environment.

1. The principles of our research
We have made this research guided by the need of getting a real feedback from the spectator’s emotional involvement in the action of the movie they are watching. The course of the research is linked to the breathing process. The emotional involvement of the human body physiologically translates into certain hormones being released into the bloodstream depending on each state of mind - uncertainty, immediate danger, dread, fear, joy, love, happiness, etc. These substances modify the heart rate, namely increase the pressure of the blood flow and thus the individual’s oxygen intake and CO2 release varies depending on the stimulus. If we measure the amount of CO2 produced over certain periods of time we could obtain data that reflects the spectator’s degree of emotional involvement, either at a specific moment or for the duration of an entire movie.

This study can be applied to any cinema room with an audience. The direction of developing this research aims at realizing an automated measuring system that can support itself mostly by harvesting energy from the analyzed environment, but without having any effect on the measured values.

2. The objectives of the research
Our first objective is to make the measurements without affecting their quality and precision.

The second is to integrate the energy harvesting equipment into the data collection environment without modifying the precision or the quality of the results. They will be used for produce more electrical power needed to power the equipment.
The third objective represents our wish to constantly improve this method of harvesting energy in order to make it more and more independent from the electrical network of the original monitoring system.

The forth objective is to store the obtained measurements for a longer period of time in order to be interpreted and to get the expected results. To do this we will use a database management system stored on a server.

The last and probably the most important objective is to make an integrated software that monitors can interprets the results we obtain. This program will be mostly developed by using high level coding that will provide a user friendly interface. The interface will have intuitive menus and will include commands for real time access to the information stored in the database.

3. Measuring methods. The best alternative

There is a number of measurement methods that we have taken into account in the course of our research. This allows us to improve new measuring techniques and to develop the research for several fields of interest. In the future we estimate the possibility of extending these methods in order to diversify the value and the quantity of the data acquired from the measurement area.

From all the methods used, we deem worth mentioning only those we considered appropriate for the objectives of our research. We believe that our research opens new directions of development using the above mentioned methods. This way we will bring our contribution to ensuring a better academical cooperation in this particular field and in the adjacent fields as well. The ideas integrated into the development of this system will not only guarantee a scientifical sustainability of our research, but will also be a component of development in the technical field.

The first method is to use the mathematical integral applied on the function of the space determined by the room. Namely Cauchy’s integral formula of obtaining values from points that are inaccessible from the inside of the measured area, knowing the values of the functions on the border [1].

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Figure 1. Cauchy integral formula applied

Let $G$ be open subset, non-void, conex in $\mathbb{C}$. The function $f$ is completely derivable in a point $z_0 \in G$ if there is the limit:

$$f'(z_0) = \lim_{z \to z_0} \frac{f(z) - f(z_0)}{z - z_0}$$

In the case where the function $f$ is completely derivable in each point in the vicinity of $z_0$, this is called holomorphic function in the point $z_0$. 

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The notion of holomorphy extends the notions of derivability and continuity from real analysis to the complex one.

If we refer to the values of CO2 amount we can reach the research level where we precisely establish the concentration in any inaccessible point within the measuring area. We have to underline the fact that the audience cannot be disturbed to make measurements during the show, therefore each spectator represents an inaccessible point in the cinema. This method represents a direction for our future research due to its complexity, which involves high costs and a large amount of resources, but offers in return integrating developments in the fields of mechatronics and technical systems.

The second measuring method consists of using sensors that are installed at a certain level in the room. The sensors are attached to the electronic equipment used to transfer the data to the database server. The method consists of making a complex network of sensors that need a high amount of resources and a high amount of power source. The results of such a measurement can be influenced by the existence of some currents inside the room or by the audience moving across the room during the performance. There is definitely some lack of precision involved. This is due to the amount time when the CO2 is produced and the moment of the measurement. We cannot precisely control the lapses of time between which we perform the measurements. The gas spreads into the room unevenly, making it very difficult to establish correlations between certain scenes in the show and how the spectator emotionally connects to those scenes.

According to our research, the most efficient method of achieving the objectives we have set is to measure the CO2 concentration in the tubes of the air conditioning system. This particular method has the advantage of not being influenced by external factors. We can always measure new quantities of CO2. We precisely establish the time periods over which we make the measurements in order to link them to the sequences in the movie. And the most environmentally friendly advantage is the fact that the system harvests energy to power the sensors. The costs of implementing such a system are reduced because is no need to have a vast network of sensors (Figure 2), like in the case of the previous measuring method.

4. Harvesting energy for sensors
In the last few years, radio, microprocessor and sensor technologies have made considerable advancements enabling the use of wireless sensor nodes (WSN) for the monitoring of several surveillance and control systems. Battery technology evolution not have the same rhythm with these enabling technologies for wireless sensor networks, so battery powered nodes must be replaced frequently.

An ingenious solution is the use of energy harvesting devices will be created so that will feed from ambient sources such as: electromagnetic, light, heat or vibration. An energy harvester could extend the lifespan of network node without having to change batteries.
Harvesting localized flow power from HVAC systems then offers a method to power a sensor and low power radio that can be run on low duty cycle with as little as 100 µW [1]. HVAC systems represent a convenient point to monitor air quality and safety for public buildings.

These examples will begin to reach a large potential for energy harvesting and HVAC systems will provide power for many sensors that could be used around air ducts or inside them.

There are plenty of strategies harvesting fluid flow, some specific to HVAC systems and some with broader applications.

Even though many studies have been conducted to harvest energy from the fluid flow, there is still a gap in the ability to harvest.

Many systems are capable of providing 100 µW need to power as a wireless sensor node, but few can do this across the range of flow rates specific to HVAC ducts, especially at lower speeds of 3 m/s.

Myers et al have added turbines piezoelectric and managed to obtain a reduction in the rate of about 2.5 m / s [2], but the equipment rotation is not desired performance.

The aim of the experiment is to achieve 100 µW in HVAC.

When the piezoelectric material is deformed, it converts mechanical energy into electrical energy through the crystal's structure.

This version offers high performance at relatively low flow speed, and ideally will provide the required performance for a wider range of flow rates than other variants of Harvester.

Small cross-sectional area exposed to the air flow and the size of this device make it an ideal energy harvester for HVAC systems. Figure 1 shows a line drawing to familiarize with the basic principle that operates harvested.

This design is suitable for environments where the flow direction is unknown.

For HVAC unidirectional environment, this issue is not important.

For these reasons, this device offers competitive performance in its intended application of harvesting from HVAC flow.

Heating, ventilation and air conditioning (HVAC) is technology for indoor and vehicular environmental comfort.

Its aim is to provide thermal comfort and acceptable indoor air quality.

For larger buildings, Variable Air Volume (VAV) HVAC systems have proven to be much more efficient which significantly improves efficiency and lowers cost.

Power generation between 100 - 3000 µW for flow speeds in the range of 2 - 5 m/s are sufficient for powering a sensor and wireless radio of a node.

The simple design of this energy harvester, if produced in bulk, offers an inexpensive solution for powering wireless sensor nodes in and around VAV HVAC systems.

Figure 3. Diagram illustrating idea behind the operation of the harvester
5. Storing the measured data
In order to have a rigorous research one needs to store the data over a medium-to-long period of time. The information has to be available for processing and interpreting for a statistical, or any other kind of nature. The data obtained by the sensors is stored into the database installed on a SQL server. It is designed on the criteria of integrity and easy access. For the chart sequence we use the hierarchic model in designing and operating the database with primary and secondary key. The software automatically authorises CRUD operations (Create, Read, Update, Delete) according to the level of connectivity to the database. The access levels are activated by using credentials. The system administrator has full rights and different users can have, according to the access data, certain rights over the database operations [4].

6. System interface
For easy access to the system we came up with a software that integrates all the technology used. This is designed by using Microsoft Visual Studio, more specifically the C# (Sharp) language [5]. We realised a software product to access and process the obtained data in real time. The program is available for Windows platforms and for Windows compatible ones, thanks to the Windows Forms system we have integrated (Figure 4) [6].

![Figure 4. Software interface](image)

As shown in (Figure 4) the data is taken from the database tables and is automatically processed. The program creates a real time chart through which we can observe the measurements taken over periods of time (5 minutes in our case). The interpretation can be thus correlated with the key moments of the movie. We can therefore know which part of the movie the audience was most involved in and to what extent [7], [8].

7. Conclusions
Our system has attained the objectives we set at the beginning of our research. We have managed to establish a connection between the moments of the artistic act and the way in which the audience gets
emotionally involved during these moments. This mechatronic system can be installed into any cinema hall with an audience.

Our research has opened new horizons for the artistic production, especially from a marketing perspective. The ideas that we presented also launched new methods of research. We hope to develop them into new technical approaches. We have therefore offered new ways of research for the centres that can afford to invest serious resources in order to get results that are vital for this field.

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