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SENSOR SYSTEMS: A METHOD PROPOSAL FOR INTERIOR SPACES RESEARCH

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ABSTRACT

The aim of this study is to propose methods on research and analysis of interior spaces, by the means of sensor systems. The authors suggest quantitative observation of movement without other feedback from the occupant. The method is based on a system of sensors and technical solutions that was developed by the authors and is described in a patent with reg.№ 3895 U1 with authors Pavlina Vodenova, Desislava Angelova and Stela Tasheva.

The proposal is meant to look into the dissatisfied and/or unanticipated in the environment project needs of the occupants and based on the data analysis, to offer optimization models.

Key words: sensor systems, residential and public interior, life quality.

INTRODUCTION

The construction of a new building and even the complete reconstruction of an existing building is a relatively expensive and complicated process, related to the state legislation and various funding opportunities. In contrast, changes in furniture depend mostly on the wish of a certain end-user and have no detailed legislation regulations, they are most often not administratively controlled. Thus, they happen faster, but still depend on the available – already built – architectural base, building structures and installations, as well as on the conditions for their changes. Still the invested funds and efforts are substantial.

The "speed" of contemporary pace of life and the key role of technologies (Brown 2014) are well known today. These factors, together with the overall, rapid transformation of social order in terms of traditional status of personalities and social groups, are the main catalyst for the modifications in the functioning of occupied (private or public) spaces in the last decades, as well as in interior and industrial design as a whole. The selection of used materials; the expected durability and frequency of their replacement; the technological means and equipment; the number of functionalities and elements of domesticity are altering in parallel, creating a complex puzzle.

We know that the changes in the interior can lead relatively quickly to improvement the life quality. They can provide comfortable, hygienic, and effective living conditions, corresponding to the new social processes, less time for service and more time for work and rest, successful prophylaxis against various diseases. It is also possible that they facilitate specific groups of users, lead to a decrease in energy costs and to many other benefits. The active but thoughtful renovation of interior spaces can save larger architectural changes or reduce the funds needed to maintain the environment.

However, it is difficult to fully predict the results of interior changes at the level of project engineering and clients' and designers' expectations often do not meet reality.

The paper is aiming the introduction of a method for interior spaces research using the means of sensor systems. The purpose is to reveal and test dissatisfied and/or unanticipated occupants' environment needs. Based

on the revealed feedback from the occupants needs, There should be offered a more optimised model in terms of space.

The hypothesis we maintain is that there is a difference between what people express as a wish to have as functionality and furniture, and what they really are using in their daily routine. The proposed method will help to find and outline these differences.

MATERIALS AND METHODS

Sensor systems are not something new. There are European and American patents that relate to different aspects of interior space. Most of the patented systems work to improve and adapt the microclimate in a premise (lighting, air conditioning and video surveillance) to the health and lifestyle status of the occupant.(refer to EP 2 966 371 A1; EP 2 878 261 A1). The above-mentioned patents, for example, are aimed at remote monitoring and ensuring the comfort of living of elderly people who live on their own.

The patent of the Swiss-Sweden transnational corporation ABB is the most exhaustive and wide-ranging. (WO 2018/122582 A1). It offers a system of sensors that totally controls the interior environment in residential or public premises and adapts it to the personal preferences of the occupants. The system controls the air-conditioning devices, lighting, musical environment, domestic appliances, "smart furniture" and other appliances that can be managed remotely. There are two analysed ways to do this: when the occupant enters the room (by RFID technology or a smartphone connection); or remotely – from another building (for example, for remote surveillance of people who live alone or when leaving the workplace and going home).

There is also a patent that uses sensors on the moving parts of the furniture for the purpose of their safe use (GB2423241). For marketing and security purposes, there are many options for spatial localization of people with a subsequent interaction with the objects around them.

Security and smart systems, as well as "Smart Home" conceptions – with interactive smart systems, also use qualitative movement monitoring. The purpose of these systems is a subsequent automatic action or production after a movement has been registered: switch on/off lighting/heating units, alarm systems, information blocks, etc.

In addition, movement trajectory in urban and interior environment has been an object of analysis in many research studies in 20th and 21st century. Different models focus on the safety and effectiveness of movement and space use in urban areas and systems. Many communication studies and systems emphasize mechanical means of movement, their synchronization and forms of felicitous use (Raicu, Costescu, Rosca 2013; Rosolino, Vaiana and others 2014). Other studies concentrate on spatial behavior of people in urban environment, according to their physical abilities and trajectory choice. we know about the work of Space Syntax Laboratory (2021) in this aspect, where, by systematizing of forms of spatial behavior as figures, elements and trajectories, a more complete and active assessment of urban and spatial environment is accomplished, facilitating the planning and design processes.

At the same time, there are a lot of ergonomic studies on the frequency of different movements, of human body tension, and of risk factors in the long term caused by the interior, and the furniture. A statistical research on the territory and ways of movement, convenience and ease of access to different zones and sectors of the furniture environment for various production and trade premises and activities is known and conducted. For example, the work of Troy and Kumar (2010) is an

effective comparison of existing systems for assessment of the ergonomic risk.

In contrast with the existing systems of sensors mentioned above, that are mainly aimed at improving and adapting of the microclimate in a certain space in compliance with health and personal features of the occupant, the here proposed approach is focused in analysis and assessment of the relationship between existing interior spaces and the actual movement needs of their occupants. The method is based on a system of sensors and technical solutions that was developed by the authors and is described in a useful model with reg.№ 3895 U1 with authors Pavlina Vodenova, Desislava Angelova and Stela Tasheva. The authors here suggest quantitative sensor movement monitoring without direct oral or verbal feedback from the end-user in order to test dissatisfaction and/or unanticipation in the environment project needs of the occupants. The signals from the sensors provide an unobtrusive but fully trackable data flow.

Unlike camera images, sensors make it possible to obtain a set of immediate and at the same time statistically significant data about users without violating their privacy. This ensures anonymity and inviolability during the research and, in turn, guarantees the reliability of the data collected.

The system consists of sensors, a controller and a computer connected to it, that register the movement intensity related to a specific piece of furniture and specific functional zones. The data obtained are processed through a special table model and coefficients for analysis and final assessment, showed below. Thus, the suggested method makes it possible to make multiple recordings for a long time and to statistically process the collected data. It examines users' movement and registers the spatial dimension of their activities, taking into account the different time periods.

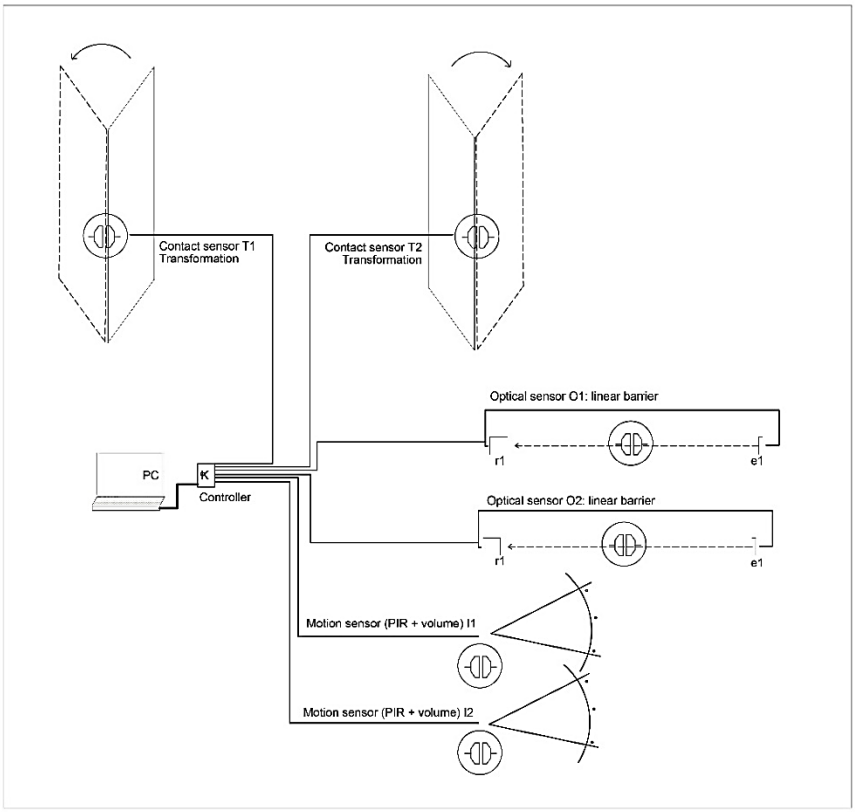

Figure1: General scheme of work (Vodenova, P., Tasheva, S. & Angelova, D., 2020)

The algorithm of the methodology implementation consists of the following steps:

1. A creation of graphical description (scheme) of the premises.
2. A selection of key points in space and assessment planes. A graphical and tabular record of these points.
3. Placement of sensors in the selected planes and points of the premises.
4. Connecting the sensor network to a chip from an appropriate platform (for example Arduino – Arduino.cc, 2019).
5. Transforming the results of the frequency of crossing the planes and the movement in a tabular record
6. Graphical record of the results on the premises scheme.
7. Calculating the results on a daily basis as well as on a frequency basis in a certain time tolerance.
8. Comparative analysis and evaluation of the efficiency of the projected functional zoning and the intended transformations.

The sensors used in the scheme are connected in a physical network with an Arduino controller. The data processed by the controller is recorded real time in a computer. The research of the interior spaces through the model that we suggest should be conducted several times (24-hour cycles) in a period based on the chosen interior zones and the forms of habitation.

There are three roles for the applied sensors, called “point”, “linear” and “spherical”. “Point” sensors – for example the contact sensors (T1 and T2 on fig. 1) could follow the frequency of opening of a joint or a “point” on the chosen product (fig.2). The input and output devices of the contact sensors are connected in a network (parallel) and reach the controller (K) that sends a signal to a PC, where the information is processed. Thus, they register activities, related to the use of closed storage volumes, as well as furniture transformation (drawing of additional surfaces for eating, sleeping and working, and for this purpose the sensors are placed at the zone of the transformation mechanism or section.

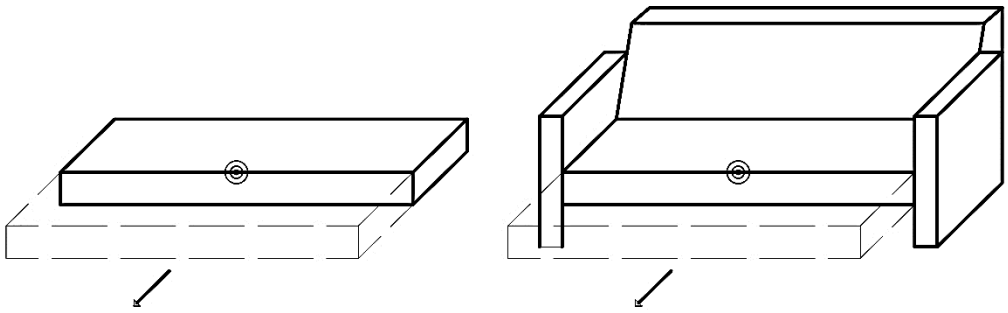

Figure 2: Placement and role of the “point” sensor (T1 and T2)

“Linear” sensors (the optical sensors O1 and O2 on fig.1) monitor the frequency of crossing of distinctive planes of the interior. They are often called “barrier” sensors, as the presence of several “beams” forms a plane barrier. These sensors are suggested to be used to follow and count activities like sitting or lying on pieces of furniture with a different main function. In fact, people’s spatial behavior in the interior is not always formalized. Therefore, by choosing different width and depth for sensor barriers installed on beds, we can, to a certain extent, register the rate of their use by the occupant. For example, crossing the plane that is 30 cm away from the bed edge represents seating and

crossing the plane that is 60 cm away – lying of the user. (fig.3). To register these activities, we use vertical linear sensors, set at 60 cm from the outer edge of the surface used to lie on, which cover more than a half of the range of the functional surface for the activity sleeping. (fig.3 O2). To register the activity seating, we use vertical linear sensors, set at a distance 30cm away from the front edge of the seating surface, which cover more than a half of the range of the functional surface for the activities work and rest (fig.3, O1).

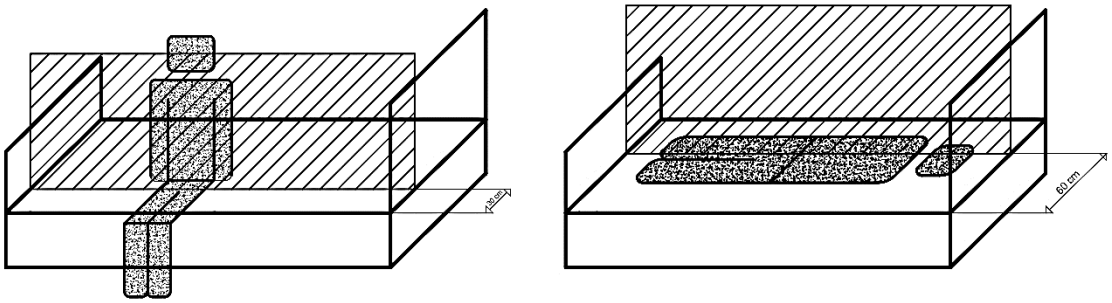

Figure 3: Place and role of the "linear" sensor (O1 and O2)

This type of sensor is also suggested for monitoring the activities of food storage and preparation. For tracking these activities, the sensors should be placed in front of the plane of the closed volumes or shelves. The optical sensors (O1 and O2) consist of a broadcaster and a receiver that are connected, and the movement that crosses the line between them is tracked by the change in the broadcasted and received signal. The elements of the optical sensors are connected by a network (parallel) with the controller (K) that sends their signal to a PC for processing.

The sensors that we call "spherical" (I1 and I2) are PIR and track the changes in the immediate area, that is defined by a certain radius, and they work through infrared transmission. These sensors are suggested for tracking the activity siting on a piece of furniture for which this is a main function. The outputs of I1 and I2 are connected through a network (parallel) with the controller (K) which sends their signals to a PC for processing. Their precision at assessing the interior zones is set for a radius 2-2.5 m, as this will make it possible to continuously record the active presence of a person there. The analogue inputs in the controller, where sensors can be connected are at least 6, and digital inputs – 14. With settings and additional devices their number can be increased.

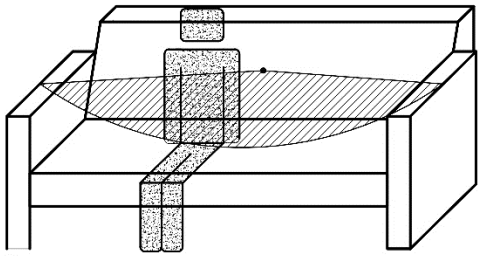

Figure 4: Place and role of the "volume" sensor (I1 and I2)

The expected result from the conducted research is presented in an example table 1, where the number of sensor signals is N for a 24-hour period.

Table 1: Sensors signals records

Time Point	Signal 1st hour	Signal 2d hour	Signal 3d hour	Signal 4th hour	Signal 5th hour	Signal 6th hour	Signal ... hour	...	Signal N hour	Total
T.1	21:00	21:14	21:20	23:20	8:00	9:30	12:00		16:00	N1
T.2	21:22	21:32	21:50	8:00	9:00	9:30	12:00		15:30	N2
T.3	21:01	21:14	21:21	23:22	8:01	9:31				N3
T.4	21:23	21:34	21:51	8:01	9:01					N4
T.5	10:01	11:02								N5
T.6	16:06	18:04								N6
T.7	12:30									N7
T.8										N8
T.9	12:15	15:15								N9
T.10										N10
T.11	13:00									N11

RESULTS

Variating types of sensors and technological elements, and different research schemes, could be applied for different interiors and forms of occupation (constant, seasonal or short termed.)

Based on the results in the table, it is possible to calculate:

- Coefficients of intensity of zones use (based on the number of signals for 24 hours). N1, N2, N3, N4, N7, N10, N11.
- Coefficients of transformation (based on the use and the frequency of transformation – number of signals for 24 hours). N5, N6, N8, N9.
- A diagram of the dynamics of time saturation, for assessment of the zoning – work and rest.

So, the sensor system makes it possible to assess the functional space zoning and the rates of use of space, through a coefficient of passing; and the real role of furniture rearranging process or the possible mechanical transformation based on the frequency of their use, an also the intended versus unintended furniture usage based on the "day-night' circle.

DISCUSSION

A common analysis in interior design today often includes the "user persona" as a characterization of an average user or customer who interacts with the product. he here proposed research method is focused on the movement and only the movement, no matter who is the actor-persona conducting it. As it is connected with the real movement, it has various limitations, especially when the reasons for, and as well as the one "executing" the movement stay unidentified. But, based on the data received and the found coefficients, the method facilitates the creation of models for interior space design, even including new or changing zones and activities through once traced users. It will also give grounds for recommendations of the types of materials to be used and the scale of implementation of modern technology solutions.

This approach allows the approbation and improvement of the living environment, and also the creation recommendations for reconstruction in compliance with the changing lifestyle and aimed at improving the occupants' quality of life.

CONCLUSIONS

"Architecture… expresses the current state of a social and cultural environment...

but also the metamorphosis in the very perception of the chosen processes and solutions", writes Maria Davcheva (Давчева 2015:101). Interior and furniture design follows the same path. We believe the proposed here sensor method could be applied in the research on the dynamics of residential and public interior occupation, and, in particular, in the ergonomic, functional, and geometrical research of contemporary living space outrunning the gradual conscious exhaustion of ideas and design concepts. Further application and redevelopment of the sensor approach and configuration could be also motivated by urban or interior systems with narrow specialization (like hospitals, industrial buildings, etc.)

„When researching the history of furniture, one observes that certain themes are constantly renewed and returned“, notices Regina Raycheva (Райчева 2014: 3). Will it be possible to predict those with the proposed sensor approach? Why not.

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