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DATABASE APPLICATION OF SMART MONITORING FOR RELIGIOUS HERITAGE CONSERVATION AND SECURITY

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Abstract

A database application is developed in order to apply the smart home concept to a monitoring system for religious art objects conservation and security. The automated control of the environment is done with a wireless sensor network that measures inside environment parameters such as temperature, humidity, luminosity, etc. Measured values are stored into a dedicated database especially designed to allow data processing and decision making. Different actuators are used to action the equipments placed into the monitored space to adjust the environment parameters that affect the art objects integrity or their security. The database application used to manage the sensors, the monitored objects and the applied procedures is described in detail.

Keywords: monitoring system, smart home, wireless, sensor network, art conservation

1. Introduction

The goal of a database is to offer fast access to information regarding a particular domain.

Few public sensors databases are described in the literature so our aim is to create one with application on smart monitoring of religious heritage conservation.

Antelope [1] is a database management system (DBMS), developed as a collection of software programs used to collect data for an outdoor environmental monitoring system. It offers near-real-time data processing features. Antelope has an open architecture and runs in Unix environment on Linux or Macintosh OS. It supports different programming languages such as C, Perl, Python and TCL/Tk allowing development of specialized software for various applications. Antelope is extended used in seismic monitoring systems by geosciences specialists.

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Another database for sensor networks, TinyDB, was designed as a query extracting information from a network of TinyOS sensors, with a simple SQL-like interface [S. Madden, W. Hong, M. Franklin and J.M. Hellerstein, *TinyDB Web page*, 2003, http://telegraph.cs.berkeley.edu/tinydb]. TinyDB collects data from the environment motes, extract the relevant data and routes it to a central node [2]. It allows power consumption control on a smart sensors network which consists of tens or hundreds of autonomous nodes.

Many public datasets can be found in the literature and online, but usually the collected data comes from outdoor sensors. Crawdad is a community resource for archiving wireless data collected from different projects such as queensu/crowd_temperature dataset which contains data about the outdoor temperature collected by taxis in Rome, Italy, in 2015 [M.A. Alswailim, H.S. Hassanein and M. Zulkernine, *CRAWDAD dataset queensu/crowd_temperature*, (v. 2015-11-20): derived from Roma/taxi (v. 2014-07-17), 2015, https://crawdad.org/queensu/crowd_temperature/20151120, https://doi.org/10.15783/C7CG65].

Smart home concept [3] is applied in order to offer automatic control of an indoor environment such as a museum, an exhibition, a church or even a warehouse where various art pieces are kept.

The monitoring system consists of a sensor network [*The World of Sensors Overview of Products for Factory Automation*, Part no. 103897, Pepperl+Fuchs International, Germany, 2015, www.pepperl-fuchs.com] with a multitude of nodes, the communication component and the central processing node. Tzortzakis et al. describe in [4] a monitoring system for analysis of sculpture and large monuments focusing on the laser-based measurements made in outdoor environments. Most heritage monitoring systems developed until today are focused on natural disasters and possible conservation methods of cultural buildings. One of these is described by Ceriotti et al. in [5] and it is deployed in Torre Aquila, a medieval tower in Trento (Italy). The indoor environment continuous monitoring is essential for heritage conservation and security. It has to be efficient and feasible.

A wireless sensor network (WSN) [6] is used by the religious heritage monitoring system in order to control different parameters such as temperature, humidity, air quality, light intensity, etc. Different indoor heritage monitoring systems are presented in the literature. Maria La Genussa et al. describe a heritage monitoring system of an Italian museum based on an experiment about indoor temperature and relative humidity (RH) monitoring [7]. This experiment shows two aspects of thermal-hygrometry and levels of indoor air quality intended for preservation of art works.

The sensor is a device used for interaction with the physical system that is intended to be monitored and/or controlled. An example is a sensor monitoring the temperature in a room and controlling the air-conditioning equipment [8]. Building sensors has been made possible by the recent advances in micro-electro mechanical systems (MEMS) [9].

Different types of sensors are used to monitor a variety of ambient conditions such as temperature, humidity, light intensity, air pollution, and the presence of undesired bacteria for art preservation and conservation. Other sensors can be places into the monitored space to sense the presence of objects and their movements in order to ensure heritage security. Sensors used to monitor objects for security reasons must detect movements, noises or object absence. GPS sensors connected to the worldwide GPS system can be attached to art objects in order to track the missing ones.

In order to measure temperature, humidity or other environmental characteristics, field-sensors with very small dimensions can be used. The information given by the sensors is collected and used to action the environment control system that contains different devices such as air-conditioning systems, heating devices, air treatment systems, window blinds, etc. For example, based on the information generated by the temperature sensor, the control system can decide to change the fan speed by controlling with a Pulse Width Modulation (PWM) signal or to start the heating device if the temperature must be raised. Thus, for certain temperature intervals, the PWM signal will have a different fill factor [10].

Sensors are interconnected into a WSN in order to collect more information on the monitored space. Sensor networks are highly distributed networks of small, lightweight wireless nodes, deployed in very large numbers to monitor the environment or a system, by the measurement of physical parameters such as temperature, pressure, or relative humidity. While individual sensors have limited sensing region, processing power and energy, networking, thanks to the large number of sensors, gives rise to a robust, reliable, and accurate sensor system covering a wider region. The network is fault-tolerant because many nodes are sensing the same events. Further, the nodes cooperate and collaborate on their data, which leads to accurate sensing of events in the environment.

Nowadays cheap, smart devices with multiple on-board sensors, networked through wireless links and Internet are available, so monitoring and controlling homes, cities, and the environment can be efficiently done. In addition, networked micro sensors provide the technology for a broad spectrum of applications, generating new capabilities that can be exploited for heritage conservation.

In our article, a database application for a monitoring system used to preserve and secure the religious heritage in a cathedral, a museum, a warehouse or a church store is designed and presented.

2. Monitoring system description

The principles of implementing a monitoring system for religious heritage conservation and security are presented by us in [11]. Different types of sensors are used in the heritage monitoring system (Figure 1): temperature sensors; humidity sensors (RH sensors); light sensors; air quality sensors; chemical sensors (electronic nose sensors); biosensors; movement sensors; sound sensors; weight sensors; position sensors; sensors with GPS capabilities.

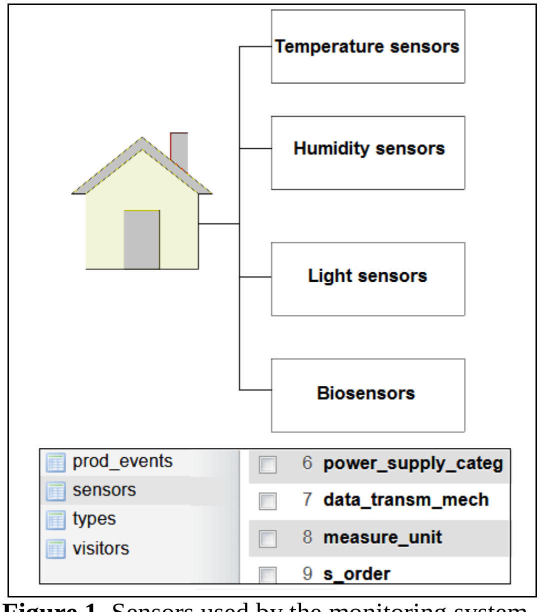

Figure 1. Sensors used by the monitoring system.

Tens or hundreds of sensors are placed all over the monitored indoor space, some of them being attached to the art objects. Sensors with specific requirements can be chosen using the Sensors Database presented in [12] (Figure 2).

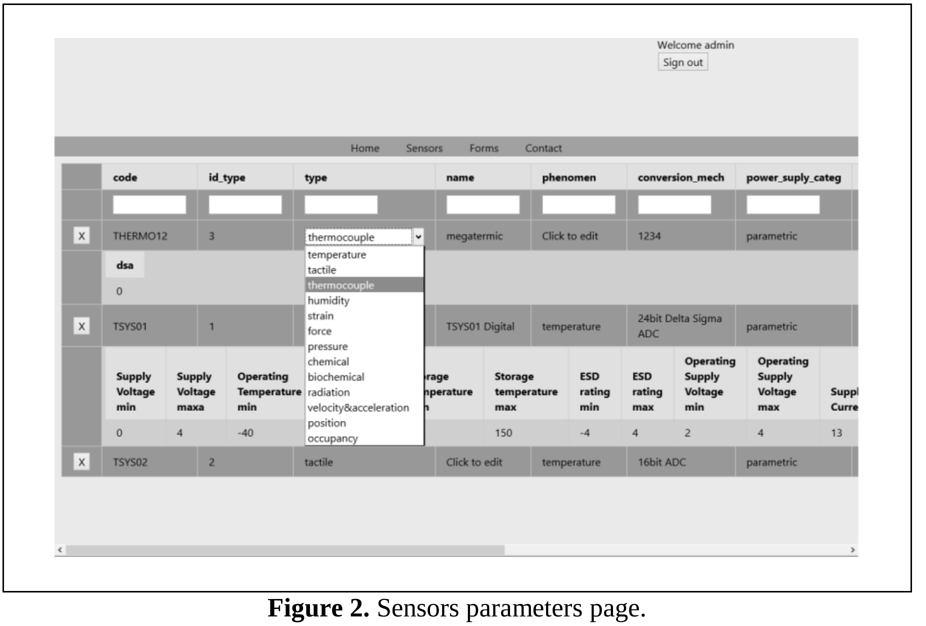

Figure 2. Sensors parameters page.

A WSN is designed with these sensors, matching the characteristics and the particularities of the monitored area. A list of WSN attributes is presented in Table 1 [13].

Table 1. Attributes of sensor networks.

Sensors	*Type*: temperature, humidity, pressure, weight, position *Size*: small (e.g., MEMS), large *Composition or mix*: homogeneous, heterogeneous *Spatial coverage*: dense, sparse *Characteristics*: active, passive
Sensing entities of interest	*Extent*: distributed, localized *Mobility*: static, dynamic *Nature*: cooperative, non-cooperative
Operating environment	*Benign* (inside monitor), adverse
Communication	*Networking:* wired, wireless *Bandwidth:* wide band, narrow band
Processing architecture	*Centralized* (all data sent to central site), *Distributed* (located at sensor or other sites), *Hybrid*
Energy availability	*Constrained* (e.g., in small sensors), *Unconstrained* (e.g., in large sensors)

The monitoring system for cultural heritage conservation is based on a centralized static wireless sensor network, with energy constraints, narrow band communication and heterogeneous composition of the network regarding the types of sensors. The WSN has three major components:

- the sensor subsystem which senses the environment;
- the processing subsystem which performs computations on the sensed data;
- the communication subsystem that ensures data exchange between sensor nodes and the central processing node.

The operations made by the sensor network are environmental parameters measurements, data dissemination, by data propagation through the network, and the collection of observed data from the individual sensor nodes to the sink which is the central node of the network. Inside the sensor network, the communication is made from multiple sources to one central node. The transmitted data can be very redundant and processing data is essential in order to get valuable information for decision making process [14].

To enable WSN-based monitoring system application, nodes have to provide the following functions (Figure 3):

- data acquisition, by different sensors with a specified sampling rate;
- communication and networking tasks: the values of the measured parameters are transmitted by the sensors to the central node, periodically or anytime an event occurs;
- data storage: values are stored in the database (DB) on the DB server;
- data processing and analysis;

- turning on the alarm system;
- scheduling and execution of the environmental control procedures.

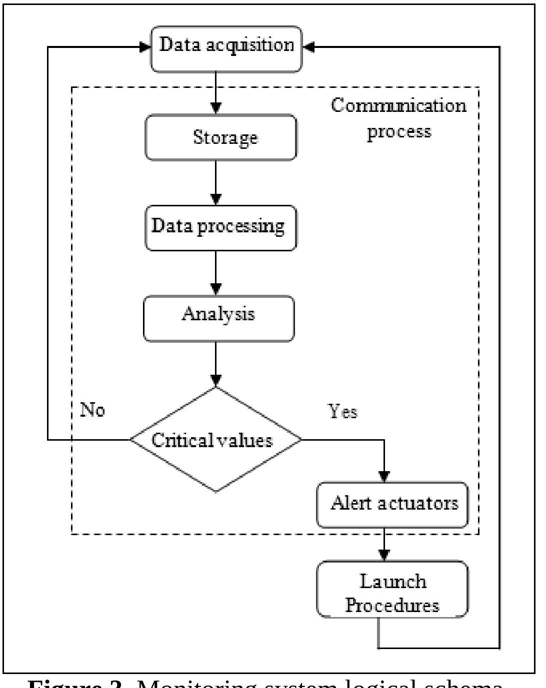

Figure 3. Monitoring system logical schema.

Data is processed in a near real-time way by comparing it to different threshold values, in order to make a decision about a possible critical situation (too hot, too cold, too much moisture, too much light, bacteria detection, too little oxygen, smoke detection, object displacement or other events).

Based on the event type, an adequate procedure is launched:

- start the air conditioning;
- start the heating system;
- start the dehumidification system;
- lower the window blinds;
- reduce the artificial light intensity projected on an object;
- start air treatment process when harmful factors (e.g. bacteria, moth, and wooden caries) are detected;
- start video recording system;
- lock doors;
- turn on the alarm sounds and lights;
- send messages to the security crew.

3. Database application

A high volume of data has to be stored and processed in nearly real-time by the central node so an efficient database application must be used in association with WSN. The conceived application consists of a relational database (DB) [15]. The database (DB) manages the art objects, the sensors, the measured values of environmental parameters and the procedures applied for heritage conservation and security.

The art objects are managed by another database designed as a virtual library [16]. All data included in this virtual library DB can be exported to the new database used by the religious heritage monitoring system. Also, the monitoring DB application can import data about sensors from the Sensors Database that can be extended for many other applications. These data are completed with other parameters like the position of sensors and the absolute and relative position of art objects inside the monitored area.

Different entities and the associated tables with it are created:

- OBJECTS and OBJECT_TYPES are defined in order to manage the art works, depending on their types (painting; statue, sculpture or bas-relief of wood, stone or marble; wool or silk textile; brass, silver or gold objects etc.);
- SENSORS, SENSOR_TYPES and SENSOR_PARAMETERS used to manage the components of the WSN and their characteristics, including their location inside the monitored area, the art objects or the Point-of-Interest (POI), which it is attached to;
- POIs are specified for different groups of art objects in order to control special environmental parameters (e.g. some paintings are placed at the top of a church wall or in the church tower where the luminosity is high and water infiltration can occur, others are located low into the space where high humidity or even flooding can affect them);
- MEASURED_VALUES, THRESHOLDS and CRITICAL_EVENTS: each value measured by the sensors is compared to different thresholds in order to detect a critical event which requires an adequate procedure to be launched by the system;
- SYSTEM_ELEMENTS, ACTUATORS and ACTUATOR_TYPES used to control environmental parameters or to monitor the location of mobile objects are managed by the DB application (e.g. air-conditioning systems, heating devices, dehumidification systems, alarm system etc.)

Twelve entities and their attributes are included into the DB entity-relation diagram with the conceptual modelling schema presented in Figure 4. The relationships between DB's entities are of one-to-many (1:M) type, meaning that the value of one entity corresponds to many values of the other entity.

Art objects of various types, needing particular conditions for conservation (e.g. maximum or minimum temperature, humidity or light intensity), are associated with different POIs, controlled by specialized devices called 'system-elements', driven by actuators.

Sensors are attached to the objects and they measure periodically the environmental parameter's values which are sent to the central node of WSN.

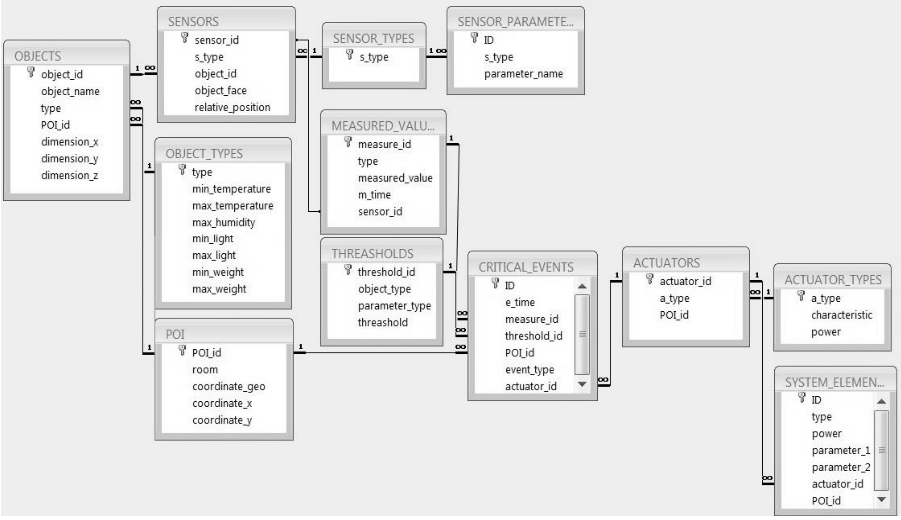

Figure 4. Database schema.

Critical events are identified by comparing the measured values with specific thresholds. If a value is out of range, a critical event is recorded into the DB. On a critical event, the actuator associated to POI is started in order to turn on a system element (air-conditioning or dehumidification systems, heating devices, window blinds, door lock, etc.).

Figure 5. Church interior.

The sensors can be placed on the inside church walls, on detachable icons, on vaults, on chandeliers, inside dome, among paintings, on columns, on doors, on the wooden railings, on the edges of the floor and on every valuable object in the cathedral (Figure 5).

Figure 6. Church objects.

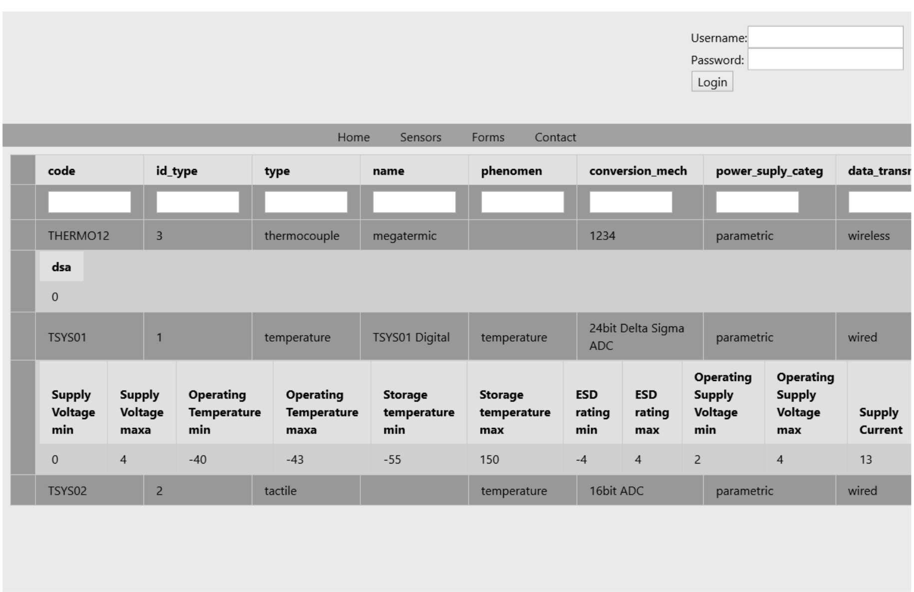

Figure 7. Login page.

GPS active sensors will be attached to those art objects that can be stolen (Figure 6). These sensors are continuously tested for presence. If a GPS sensor is not responding any more, a critical event of 'missing object' is recorded and an alert is transmitted to the security crew in order to start the recover procedure. These sensors are connected to the Global Positioning System, so the missing objects can be located and recovered.

The central node of WSN is the DB server installed on a powerful computer. The DB access is granted by the administrator only to authorized staff, based on the username and the password (Figure 7).

This database is implemented using Procedural Language/Structured Query Language (PL/SQL) which is the recommended database programming language for large-scale professional systems [17]. Sensors types and parameters are inserted into the database using dedicated designed forms (Figure 8). The database was populated with specific data and different queries were made in order to test the application.

The DB server can be accessed by a web server, using a web application, by many authorized users simultaneously. It is accessible locally or remotely using any web browser. Alerts can be also transmitted to many devices, such as mobile phones or tablets, used by the security staff on field.

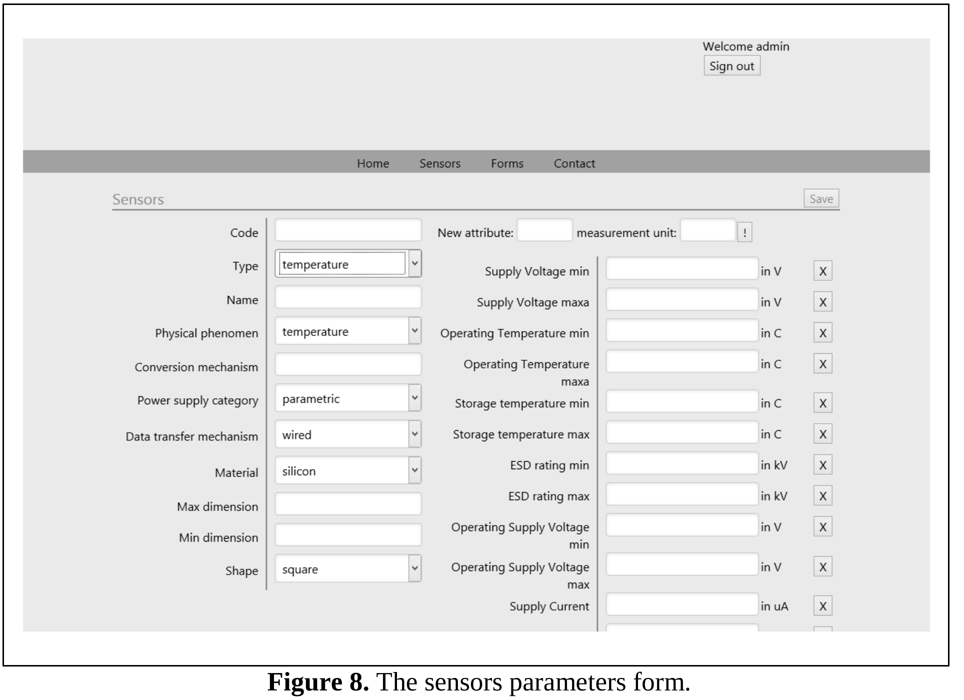

Figure 8. The sensors parameters form.

4. Conclusions

Monitoring religious art objects is an important goal of the conservation and security process. Conservation of art and religious objects is done depending on the monitored object type: paintings in watercolours, oil painted icons, icons on glass, wood icons, stained glass, sculptures, statues, handmade textiles, clothes, silver objects, gold objects, books, hand-writing manuscripts etc. Different conditions must be ensured for each type of object and material (paper, silk, textile, wool, metal, glass, wood, stone, marble, etc.)

A wireless sensor network which involves data acquisition, network communication, data storage, processing and analysis, is used to measure the environmental parameters and the measured values are stored into the designed database. When critical events are identified, different actuators action the appropriate devices used to control the environment. A database application that manages the monitored art objects, the sensors, the actuators, the environment control devices, the measured values and the critical events is conceived and presented.

References

[1] ***, *The Antelope Relational Database System Datascope: A tutorial*, Boulder Real Time Technologies Inc., USA, 2002.

[2] S. Madden, M. Franklin, J. Hellerstein and W. Hong, ACM T. Database Syst., **30(1)** (2005) 122–173.

[3] R. Harper, *Inside the smart home,* Springer-Verlag, London, 2003, 15–40.

[4] S. Tzortzakis, D. Anglos and D. Gray, Opt. Lett., **31(8)** (2006) 1139–1141.

[5] M. Ceriotti, L. Mottola, G.P. Picco, A.L. Murphy, S. Guna, M. Corrà, M. Pozzi, D. Zonta and P. Zanon, *Monitoring Heritage Buildings with Wireless Sensor Networks: The Torre Aquila Deployment*, Proc. of the 2009 International Conference on Information Processing in Sensor Networks (IPSN'09), IEEE Computer Society Washington DC, 2009, 277-288.

[6] K. Sohraby, D. Minoli and T. Znati, *Wireless Sensor Networks - Technology, Protocols, and Applications*, John Wiley & Sons, Hoboken, 2007, 1-12.

[7] M. La Gennusa, G. Rizzo, G. Scaccianoce and F. Nicoletti, J. Cult. Herit., **6(2)** (2005) 147-155.

[8] J. Cecílio and P. Furtado, *Wireless Sensors in Heterogeneous Networked Systems*, Springer International Publishing, Switzerland, 2014, 6.

[9] N. Maluf and K. Williams, *An Introduction to Microelectromechanical Systems Engineering*, 2^{nd} edn., Artech House, Norwood (MA), 2004, 89–96.

[10] L. Vornicu-Albu, *Electronic Transducers* (*Traductoare electronice*), PIM, Iaşi, 2013, 56-76.

[11] V.D. Diaconescu, L. Scripcariu, R. Diaconescu, C. Zaharia and L. Vornicu-Albu, *Smart Binnacle Monitoring System for Religious Heritage Conservation and Security*, Proc. of the 9^{th} European Symposium on Religious Art, Restoration and Conservation (ESRARC 2017), I. Rusu, M.T. Nechita, E.N. Drăgoi and N. Apostolescu (eds.), Kermes, Lexis Compagnia Editoriale, Torino, 2017, 90-93.

[12] V.D. Diaconescu, L. Scripcariu, L. Vornicu-Albu and C. Loghin, *Database Sensors for E-Textiles With Medical Applications*, Proc. of the 15^{th} AUTEX World Textile Conference, Performantica, Bucharest, 2015, 1-9.

[13] C.Y. Chong and S.P. Kumar, Proceedings of the IEEE, **91(8)** (2003) 1248.

[14] L. Scripcariu, V.D. Diaconescu and C. Loghin, Doxologia, **15** (2016) 245–261.

[15] R. Elmasri and S.B. Navathe, *Fundamentals of Database Systems*, 5th edn., Addison-Wesley Longman Publishing Co. Inc., Boston, 2006, 11-32.
[16] L. Scripcariu, R.M. Diaconescu, M. Geba and L. Vornicu, Eur. J. Sci. Theol., **9(2)** (2013) 155–160.
[17] S. Feuerstein and B. Pribyl, *Oracle PL/SQL Programming*, 6th edn., O'Reilly Media, Sebastopol (CA), 2014.