Prototype of Smart Monument with IoT-based System of Early Warning

V G Spasova¹, B G Georgiev¹, P D Stefanov² and B P Stoyanov¹

¹Varna Free University “Chernorizets Hrabar”, Department of Computer Science, Yanko Slavchev str. 84, Varna, Bulgaria
²Varna Free University “Chernorizets Hrabar”, Department of Architecture and Urban Studies, Yanko Slavchev str. 84, Varna, Bulgaria

e-mail: vspasova@vfu.bg

Abstract. The preservation of cultural and historical monuments aims to draw public attention to the national heritage, which preserves history and traditions and distinguishes us from other nations. The preservation, restoration and maintenance of any historical monument require skills, knowledge, resources, time and effort. The aim of this article is to present developing a prototype of an early warning system for disasters, mounted on a biggest monument in Varna from the socialist history period. This multidisciplinary project consists of two parts - creating a model of the monument at a scale of 1:20 and installing an IoT based solution, built of sensors and controllers.

1. Introduction

There are many historical monuments in the city of Varna - some maintained and preserved over the years, others forgotten, vandalised and abandoned. Regardless of the time of its creation, the monuments recreate the historical time and the values in it. The challenge is to turn a monument created 45 years ago into a smart monument for the benefit of the people.

The modelling of the monument was carried out within the framework of "City Lab 2.19 - workshop for revitalization of the urban environment". The work is led by arch. P. Stefanov. After presenting the site upon receipt of the workshop, participants inspect the site, where they find out the condition of the building, the complex geometry and the beautiful view that opens from the site in front of the entrance.

At the second stage of the project, based on the developed model, a prototype of a system for adding intelligence to the monument was built, helping for early warning of accidents. Using Internet of Things technology to equip a smart companion involves connecting a variety of devices to a network and to each other based on the Internet.

2. Related works

A web-based navigation system with air quality monitoring for a smart campus is presented in [1]. In [2], a technology of smart campus platform based on situational awareness is constructed. A novel design and implementation of an intelligent platform supporting the Internet of Things is proposed in [3]. In [4], a data flow framework employed by the Safeguarding Cultural Heritage through Technical and Organisational Resources Management (STORM) platform and acoustic sensors is designed. Architecture developed to process and store data coming from a huge amount of distributed IoT sensors is presented in [5]. It is a brokered task queue system distributed over a private cloud infrastructure. In [6], in order improve the fruition and the enjoyment of cultural heritage spaces an IoT system is
designed. The architecture of an IoT infrastructure to be used for the monitoring of large scale monumental structures is described in [7]. The proposed infrastructure is suggested to be used in an individual city scale scenario.

3. Project Implementation

3.1. The architectural model

The workflow of the modelling process passed thru next steps:

1. Find construction drawings from the local municipality archive.
2. Digitization of the raster drawings
3. Detailed 3d modelling and creating detailed 2d parts from the model.
4. The vector drawings are printed in 1/20 scale and superimposed on sheets of cardboard.
5. The main bearing vertical elements are glued with the horizontal slabs. Then the outer shell is made and the elements begin to diverge from the drawings, which is normal in view of the complex shape.
6. The sculptures of the Bulgarian girls and the Russian soldiers are cut from expanded styrofoam. The front two walls of the model are movable, which allows studying the complex function that was housed inside.

The work process begins with scanning existing drawings printed on paper (fig. 1). For this purpose, is used a wide-format roller scanner which is more suitable for large sheets of construction graphics. Scanned drawings are imported as raster images into AutoCAD, where each scanned image can be scaled using dimensions written in the original drawing to the real size that is most suitable for digitization (fig. 2). Once the images are at the correct scale starts the redrawing with vector lines of all plans, sections and facade views. During this workflow, certain inaccuracies with the sizes are often detected, which is quite common when drawing by hand. All 2D drawings are exported as separate vector files, which are then imported into Sketchup, where the 3D model of the building is made. The plans remain horizontal, and the sections and facade views are rotated perpendicularly and adjusted to their respective positions in the 3D space (fig. 3). Plan views are used to draw polygons and then extrude them to the correct height using the sections. In this type of 3d reconstruction, all faces which are in a projection view on the original drawings are restored to their real size as they are needed in the scale model.

When designing the scale model, it is important to consider the limitations of cardboard, glue, the final scope and the stability of the model during transportation. A base of extruded polystyrene with a thickness of 10 cm is prepared. Such a base is suitable for building a large-scale model and eventual transfer. All vector plans are printed on a roller plotter on the scale of the model which is 1/20. They are used to give the basic size of the floors. Each plan is placed on a sheet of cardboard and the end points in cardboard are perforated with a needle. These points are then connected by lines drawn with a pencil. Each plan is cut with a model knife. The floors outlined in this way are glued to the heights that are in the sections. The 3D model is used to make folds of complex geometric shapes in the base, which are rotated and laid horizontally and then exported and printed in their actual dimensions. With the help of digital models to help build a model of the building takes a few days. The lack of precision necessitates slight adjustments to some elements in order to obtain an accurate layout.
**Figure 1.** Original drawings printed on paper.

**Figure 2.** 2D models in Autocad.
3.2. The early warning IoT system

For implementation of the second stage of the project three subsystems are developed:

1. Subsystem for reading the temperature and humidity of the air - is realized by placing a specialized
sensor, integrating an LED display in the highest central part of the monument and using an Arduino microcontroller.

2. In view of the diverse and numerous vegetation around the monument, construction of a signaling system in case of fire and/or smoke. It is realized by placing fire and smoke sensors located in the middle of the monument and loudspeakers for notification, placed in the highest part of the monument in the four main directions.

3. Establishing the movement of the earth layers, their marking and informing the population. This is done by a specialized seismic device-seismograph, which registers the seismic waves and registers them in a seismogram, gyroscopes placed in the depth/base of the monument, floodlights located in the highest part of the monument and directed to its base, sound indicators-speakers located on the sides of the two wings of the monument.

Two controllers have been selected for the technological realization:

1. Micro:bit is a microcontroller board that provides a quick and easy way to learn, first steps in programming and experimenting with microcontrollers with integrated sensors.

2. Arduino is a microcontroller development board built with ATmega328P – datasheet.

For both boards, they provide easy sensor management and communication protocols using open source libraries to build applications with IoT.

3.2.1. Subsystem for reading the temperature and humidity of the air

Using components:

- Arduino UNO - microcontroller development board with ATmega328P datasheet. There are 14 digital input-output (I/O) ports, 6 analog inputs, 16 MHz quartz resonator, four LEDs (one custom, connected to the 13th digital I/O port and three that indicate the operation of the board: ON, Tx and Rx), USB connector, plug connector, restart button and ICSP connector. The operating voltage is 5V. The connection to a computer is made via a USB cable USB A - USB B.

- DHT11 sensor - measures temperature from 0 ° to 50 °C and relative humidity in the range of 20% - 90%. Deviations in the values are possible, taking into account the temperature +/- 2 degrees and the humidity +/- 5%. The sensor is pre-calibrated, has a digital output and is characterized by good reliability and stability. To work adequately it needs a supply voltage between 3V and 5.5V. The maximum current it can allow is 2.5mA.

- Liquid Crystal Display (LED).

- Potentiometer - a voltage divider is used, i.e. resistor with 3 pins, one of which is movable.

Figure 5. Scheme of connections of LED.
Figure 6. Scheme of connections of DHT11 sensor.

For software implementation Arduino 1.8.10 open-source Software (IDE) programming environment is used, with the following libraries installed: <dht.h> - library for working with DHT11 sensor and <LiquidCrystal.h> - library for working with LED display.

3.2.2. Signaling system in case of fire and/or smoke
Using components:
- Micro:bit microcontroller - Micro: bit is a microcontroller board that provides a quick and easy way to learn, first steps in programming and experimenting with microcontrollers. Integrated technologies: 3-axis accelerometer, 3-axis compass, Bluetooth BLE, two buttons and 25 LEDs (5x5 matrix). The power supply is 3V through the battery connector or 5V through the Micro USB connector.
- IR Flame sensor - The module is built with an infrared photodiode, detects light from a flame (fire). It is supplied with voltage 3.3V - 5.3V and has low current consumption. The output interface is designed to provide two types of signal - analog and digital. The analog output generates a voltage with a level depending on the proximity of the flame to the sensor. The digital output generates a high level - one when the sensor part approaches a flame; has a potentiometer-adjustable trigger threshold - sensitivity.
- 80dB buzzer - a signal element announcing with a sound certain, predetermined, expected event.

Figure 7. Scheme of connections.

The software part of implementation uses the Micro: bit programming environment and the JavaScript programming language.
3.2.3. Establishing the movement of the earth layers

Using Components:

- Micro:bit microcontroller – with build in accelerometer.
- RGB LED pixels WS2812B - they can glow on their own in thousands of different colors independently of the other pixels in the chain. This type of pixel is intended for professional use and requires the use of programs to encode lighting effects. They require special controllers. Their supply voltage is 3V, which makes them extremely preferred for work.
- 80dB buzzer.

![Figure 8. Scheme of connections.](image)

The software part of implementation uses the Micro:bit programming environment and the JavaScript programming language.

In addition to all projects, a prototype board of the type "Breadboard 400" and "Breadboard 170" was used. The prototype Breadboard has 400 slots, arranged in 4 rows in length and 30 in width. The board measures 82 mm x 54 mm and has double-sided adhesive tape for easier attachment. This type of board is used for experimentation, prototyping and testing of electronic components. It allows quick construction of temporary circuits without soldering. The connection of the elements is carried out with the help of connecting wires - jumpers.

![Figure 9. Systems installation inside.](image)

![Figure 10. The model of the monument outside.](image)
4. Conclusions
Arduino and Micro:bit are one of most popular controllers for IoT open source applications, that which allows the described projects to be easily recreated in a learning environment and to be applied to various other suitable objects.

As a result of the joint project, a real architectural model of the largest historical monument in the city of Varna and a prototype of a system for early warning of disasters with the use of IoT technologies have been developed. The project was demonstrated to the Chief Architect of the city of Varna and colleagues from software companies in the city. It is currently on display in the Lobby of Varna Free University and can be viewed and tested by visitors.

All project documentation – schemes of connections and developed source codes can be fined and download on GitHub - https://github.com/BorisGeorgiev94?tab=repositories

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