Augmented Reality Enabled IoT Services for Environmental Monitoring Utilising Serious Gaming Concept

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Abstract

The paper describes an approach to integration of physical and digital worlds through aggregation of Internet of Things (IoT) service with the Augmented Reality (AR) platform, AR Genie. The solution is generally applicable, but concretely in this paper the IoT service is provided by ekoNET platform which provides the environmental data through AR based applications. The ekoNET solution is developed for a real-time monitoring of air quality and other atmospheric condition parameters such as temperature, air pressure and humidity. AR Genie is Software as a Service (SaaS) and Platform as a Service (PaaS) solution offering features and functionalities for creation and deployment of AR applications using simple and intuitive drag and drop interface requiring no programming knowledge. By extending the AR Genie platform with the ekoNET IoT service we were able to demonstrate usage of a real-time environmental data within AR mobile applications as well as to enable a new, more engaging way of IoT data visualization utilizing serious gaming and AR technologies.

Keywords: Smart City, IoT, low-cost sensors, environmental monitoring, CoAP, Augmented Reality, Serious Games

1 Introduction

The IoT concept enables creation of the smart environments connecting with the citizens and shaping the cities around the world by offering a range of smart services with aim to increase the quality of life in the cities. Connecting the environments with people requires an interface offering a rich user experience able to engage and present the relevant information that fulfills the purpose of the service. There is a need to provide a constant stream of new solutions promoting the citizen participation and involvement with IoT applications in the context of the Smart Cities. One of the disruptive technologies that are still to be widely exploited within the IoT arena is the AR which can improve the human-computer interaction within the smart environments in more engaging and entertaining manner. This is of a great importance if it is required to raise awareness about a particular issue through engagement of wider community. One of such issues is an air pollution in cities. This paper addresses this topic by presenting a novel approach in combining AR based serious game with the data gathered from the IoT environmental monitoring service.

Currently, more than 50% of people live in the cities and the UN estimates that by year 2050 cities will be home to 70% of the world's population [1]. At the same time, the citizens expect more and more from the cities including better quality of life and the latest information about various aspects of the city life, including the city's environmental conditions. For example, although cities occupy only 3% of the world's geography, they generate about 80% of CO2 emission [2]. Being "green" is important for the

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cities, not only from the aspect of the life quality of the people living in the city, but also to attract tourists, investors and businesses. At the same time, the enterprises are continuously trying to optimize the work processes and act in a socially responsible manner. To achieve these aspirations, remote monitoring of processes including hazardous gas levels at different locations of the facilities, industrial safety, personal exposure and eco-friendly solutions play an important part, in particular in the oil and gas industry. In addition, more stringent legislation are being introduced, further emphasizing the need to monitor environmental conditions and take corrective actions as soon as possible, thus minimizing the harmful impact and related costs.

Ultimately, the main goal is to raise community awareness of the importance of the environmental issues, in particular the air quality and effect on the human health of the air pollution. This task requires innovative methods and approaches in attracting large community participation and engagement in the activities related to these issues. It is therefore important to present solutions that will be innovative, engaging and at the same time educational. This paper is focused on presenting the solution in the environmental monitoring, but in general can be applied to other fields. The main idea is to create a serious game that will promote the air quality issues using a real data obtained from cheap environmental monitoring devices based on the ekoNET service and AR user interface.

The paper is organized as follows. In Section 2 the principles of air quality monitoring in smart cities are presented. Section 3 describes the AR concept and its relation to the IoT domain. The ekoNET service and the system architecture are described in Section 4. Description of the AR Genie platform and its integration with ekoNET service is explained in Section 5. In order to demonstrate the capabilities of integration of AR Genie and ekoNET, implementation, testing and evaluation of ARvatar game as a use case is given in Section 6. Section 7 concludes the paper.

2 Air Quality Monitoring

In recent years the activities related to the environment monitoring are becoming more intensive and focal point in the research projects. Special attention is devoted to projects targeting development of smart cities and smart society in general. Distributed sensing systems for portable and personal monitoring of environmental parameters are emerging as an innovative solution for data collection, combined with enhanced computational tools for the real time analysis. Projects such as the FP7 SmartSantander [3], the Japanese DOCOMO Project [4], and the Copenhagen wheel project [5] use portable sensors to measure a number of parameters including air pollution, UV, noise and/or meteorological conditions. The portable sensors are placed around the city and/or on vehicles or bicycles.

Also, the recent literature covers a number of devices for air pollution monitoring in urban and rural areas that utilize low cost sensors and wireless systems for transmission of measured data. A system that measures concentrations of gases, such as CO, NO2, SO2, and O3 using semiconductor sensors is presented [6] where the measurement station is static and there is no possibility of remote data access. In [7] the authors present a wireless distributed mobile air pollution monitoring system which is implemented and tested using the GPRS public network. The system utilizes city buses to collect pollutant gases such as CO, NO2 and SO2. In [8] the concept of a mobile monitoring system for chemical agents control in the air is presented (CO, CO2, NO, NO2 and VOC). The proposed system can be applied to measure industrial and car traffic air pollution. Data transmission uses the GPRS/EDGE radio link to transfer measurement results to the server. ekoNET system, presented in this paper has the ability to perform measurements both at a static location and as a mobile platform.

In paper [9] authors present an approach based on the statistical methods which lead to significant reduction of the number of necessary measuring points, as well as the number of required sensors while still providing reliable estimation of environment parameters across the monitored area. The paper shows that the proposed solution works quite well in the areas with slowly-changing weather conditions. The solution is verified on a mobile platform mounted on the public transport vehicles and used for measurements of environmental parameters.

The environmental monitoring solution ekoNET aims to provide a simple and cost-effective solution that can be deployed both by the city authorities and enterprises wishing to monitor the air pollution and atmospheric parameters. This paper presents the overall system architecture encompassing the ekoNET device, back-end cloud infrastructure and the integration aspects with AR Genie platform for the data presentation and user engagement using the AR-based serious game.

3 Augmented Reality

AR technology is based on augmenting (supplementing) the view of the real world with additional computer-generated content such as images, videos, sound, GPS data etc. The process of augmentation is triggered when AR markers are detected. Then, appropriate AR content is presented to the user based on the detected marker. The markers can be in the form of pre-defined images which are detected and tracked in the real-time using image processing algorithms within the live video stream [10], [11], [12], [13]. Furthermore, the marker can be a certain GPS location and orientation of the camera used for video stream capture. A typical example is the Wikitude app [14]which is used to display additional information about restaurants, tourist landmarks etc. in the user's vicinity.

The AR technology was initially used for military, industrial, and medical applications, but was soon applied in the commercial and entertainment domains. According to Gartner [15], AR is one of the top 10 strategic IT technologies of our time. The technologies which AR encompasses are: camera, location sensors, display and image processing engine. Currently, the prominent devices supporting the AR applications are the smartphones which have all the required components integrated as well as the CPU, GPU and RAM capable of executing demanding image processing algorithms. Furthermore, application distribution channels such as Google Play and iTunes enable fast and efficient deployment of applications globally. Juniper Research [16]forecasts $1.5 billion revenue by 2015 with more than 2.5 billion AR applications to be downloaded to smartphones per annum by 2017. Furthermore, it is estimated that the AR applications will generate $300 million in revenues globally in 2013 and $1.5 billion by 2015. Recently, alternative technological advances are being made in order to create dedicated AR hardware such as Google Glasses which will even further promote the AR applications and technology.

Application of AR technology within the smart city services and IoT in general is not yet widely available. FP7 SmartSantander project has published SmartSantanderRA application [17] which enables the real time access to the traffic and beach cameras, weather reports and forecast, public buses information and bike-rental service, generating a unique ecosystem for citizens and visitors when walking around the city. The application includes information about 2700 places in the city of Santander separated into different categories: beaches, parks and gardens, monuments, Points of Interest (POI), tourism offices, shops, art galleries, museums, libraries, culture events agenda, shops, public buses, taxis, bikes, parking places, etc. In terms of the public transport, the system offers information related to the locations of the bus stops and the bus lines passing through them without real-time information. The Open Cities, an EU co-funded project [18], aims to validate Open & User Driven Innovation methodologies applicable to the Public Sector in a scenario of Future Internet Services for Smart Cities. One of the key aspects of the project is to determine how to integrate open innovation methodologies within the cities and how the citizens will benefit from the Future Internet services pilots based on Augmented Reality in mobile devices.

Other applications include museum tours powered by the AR in the UK called StreetMuseum [19], interactive maps used to locate the services and their use in smart governance and a smart living viewpoint

[20] and AR markers in Madison Square in New York City explaining the smart city services available [21].

This paper introduces AR technology into the environmental monitoring service ekoNET targeting wide citizen population using the serious gaming concept.

4 ekoNET Service

Currently, the air pollution, and environmental parameters in general, within the cities are monitored by the network of static measurement stations usually operated by the public authorities. These fixed stations are highly reliable and able to accurately measure a wide range of air pollutants. However, they are expensive and require significant effort in maintenance. Subsequently, the extensive cost of acquiring and operating these stations severely limits the number of installations.

In order to address the price, mobility and availability issues, low-cost solid-state gas sensors have started to be used for measuring the pollutants in the atmosphere. The gas concentration is determined by measuring either the sensor's output current or the resistance of the sensor's tin dioxide layer. These solid-state gas sensors are inexpensive, small, and suitable for mobile measurements.

The ekoNET service provides a complete end-to-end solution for environmental monitoring following the design concepts used within the IoT domain. The system comprises the following components: infrastructure and the overall system design, follows the principles of IoT architecture reference models (IoT-A ARM) [22], so that the overall design methodology can be easily compared and potentially integrated with other IoT platforms.

The end users can query the system using a web or mobile application to get the real time measurements. If ekoNET devices are mounted on public transport vehicle the environment monitoring service can be combined with public transport service providing information about the locations of the public transport vehicles.

- measurement devices (EB800)
- back-end infrastructure
- web and mobile client applications

The exact functionality in terms of the environmental monitoring is defined by the types of sensors used within the measurement device itself. Currently, the system is designed to support two types of sensors: more accurate ones that can be used for air quality measurements and less accurate sensors that can be used to provide indications of the levels of the gases in the air. Both variants can be used indoor and outdoor and can be installed at fixed locations or mounted on vehicles (for example public transport or trucks in large surface coal mines) thus enabling larger coverage. The system also supports personal devices used to monitor personal exposure.

The back-end infrastructure and the overall system design, follows the principles of IoT architecture reference models (IoT-A ARM) [], so that the overall design methodology can be easily compared and potentially integrated with other IoT platforms.

The end users can query the system using a web or mobile application to get the real time measurements. If ekoNET devices are mounted on public transport vehicle the environment monitoring service can be combined with public transport service providing information about the locations of the public transport vehicles.

4.1 EkoNET Measurement Device EB800

The EB800 device is currently being used within the ekoNET service. It is designed in a modular fashion thus enabling connection of different types of sensors according to the requirements. The central part of the device is the main board (see Figure 1). It essentially provides the core functionality of the system such as GPRS/GPS connectivity as well as the digital and analog interfaces for the external sensor boards. All the components have been carefully selected in order to minimize the intrinsic noise generated by the internal electronic circuitry and also to prevent any noise injection into the sensitive sensor driver circuitry. In order to minimize the interference with the low-level analogue signals that sensors provide, all sensor boards are connected via the digital I2C or SPI interface.

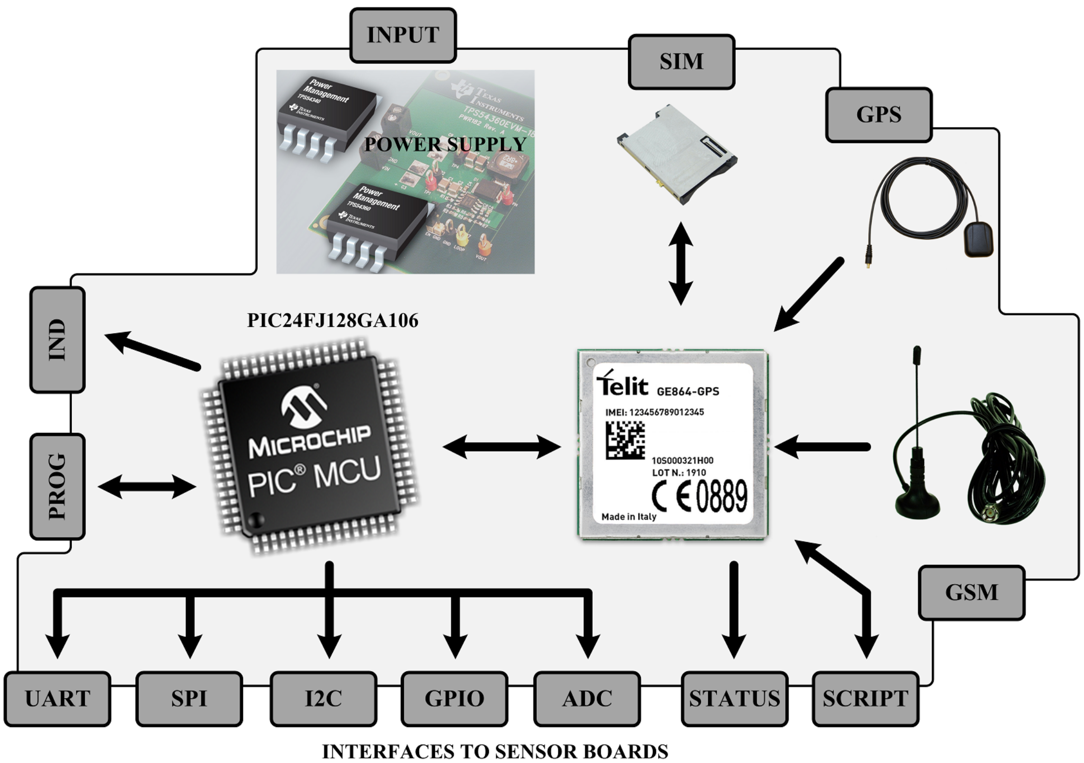


Figure 1: Block diagram of ekoNET device main board

The EB800 device presented in this paper is equipped with the following atmospheric condition sensors:

- The sensor for atmospheric pressure measurements MPX4115 (15-115 kPa) [23]
- The sensor for temperature and humidity measurements CC2D23S (-40°C–123°C, 0-100%) [24]

Sensors used to measure concentration of the gases in the air are Alphasense's B4 family electrochemical types (designed for monitoring air quality in urban, rural and indoor areas) and infrared type IRC-AT for CO2 (refer to Figure 2):

- CO2-IRC-AT (0-5000ppm) [25]
- O3-B4 (0-2ppm) [26]
- NO -B4 (0-20ppm) [27]

- NO2-B4 (0-20ppm) [28]
- CO-B4 (0-50ppm) [29]

EB800 device is also equipped with a noise sensor measuring the sound pressure up to 105 dB.

As for the particulate matter monitoring, Alphasense OPC-N1 [30]is used as particulate matter sensor, measuring all particles below 1μm, 2.5μm and 10μm in size (PM1, PM2.5 and PM10) as well as measuring the particle size distribution in a real time. This sensor solution uses Serial Peripheral Interface (SPI) and can easily be attached to the main board. The OPC-N1 already has a microcontroller for local signal processing.

Figure 2: ekoNET device with low-cost electrochemical gas sensors

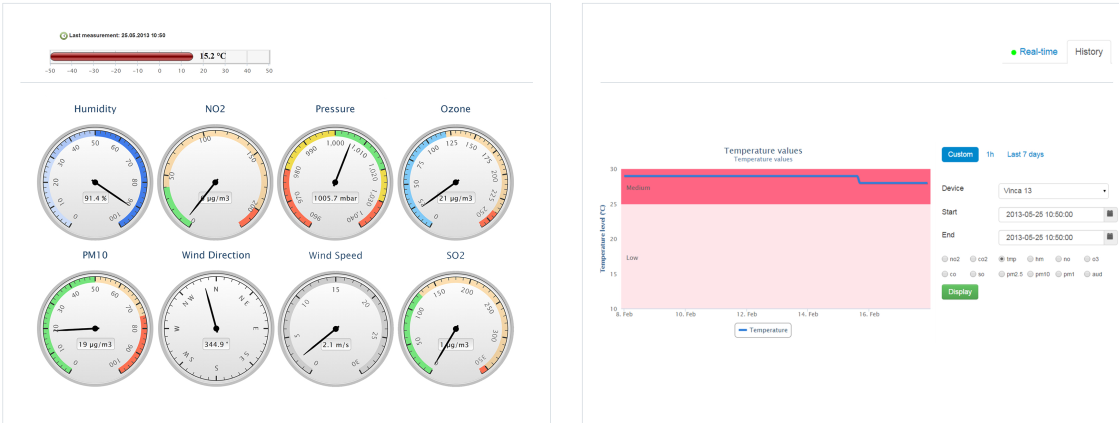
Each of the available devices is automatically registered in the Resource Directory (RD) which stores the meta information about all resources and services within the IoT platform. Data collected from the EB800 sensors are packaged into appropriate data format and sent to the back-end cloud infrastructure via the mobile network (GPRS) channel utilizing Constrained Application Protocol (CoAP). The data is stored in the database and service layer components are used to provide the data for the applications.

4.2 EkoNET Service Applications

A web and a mobile application are used to visualize collected information, including geographical location of all measurements. Web application allows user to log in and observe the measurements gathered from different sensor platforms in a real time, as well as historical data over different periods of time (see Figure 3). The data can be retrieved and stored for later analysis.

4.3 EkoNET Service ApplicationsekoNET System - IoT-A Architecture Reference Model (ARM)

IoT-A Architecture Reference Model (ARM) provides a model for the interoperability of IoT systems, outlining principles and guidelines for the technical design of its protocols, interfaces and algorithms.



The real - time data visualization *Historical data visualization*

Figure 3: Web application for ekoNET data visualisation

EkoNET system is designed using the IoT-A principles. Figure 4 shows the high-level architecture of the ekoNET system mapped to the IoT-A Architecture Reference Model (ARM) [22].

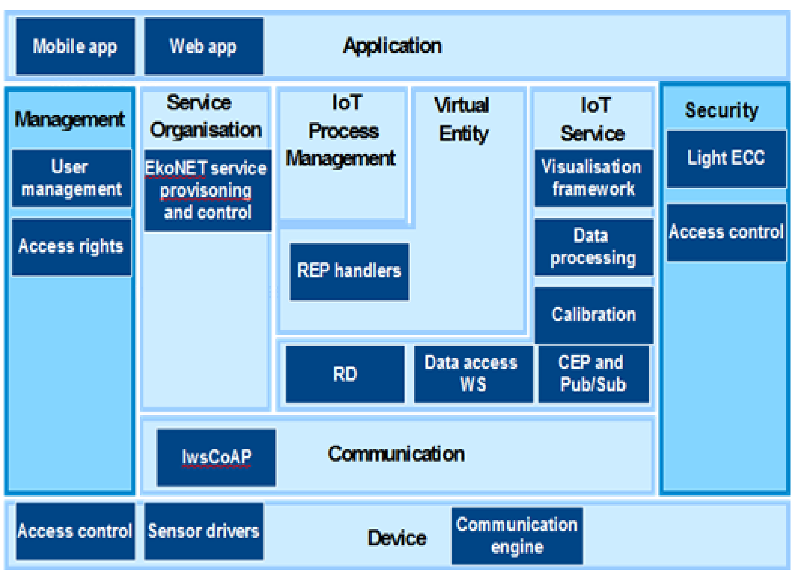


Figure 4: ekoNET system architecture mapped to IoT-A ARM

EkoNET system, by following the IoT-A ARM principles, ensures that the implemented and instantiated architecture complies with the standards related to the interoperability in terms of the protocols and functional specification of the building blocks of designed IoT system.

The ekoNET devices are connected to the ekoNET platform serving as the back-end cloud infrastructure. There are several variants of the ekoNET devices depending on the deployed location (indoor/outdoor), type of sensors used (air quality/safety) and usage (stationary/personal), but their deployment is the same in the context of connection to the cloud infrastructure. Each of the sensors has its own **Sensor driver board**. Access to sensor data is controlled using the **Access Control** component which is also used for controlling the access of devices to the cloud infrastructure. This ensures that only authorized users can access the data as well as only authorized devices can access the cloud infrastructure. The collected data from the sensors is transmitted to the back-end infrastructure via the mobile network using the CoAP [31]. utilizing the **Communication engine component**. CoAP is an application layer protocol designed to lower the complexity for the constrained networks, but also to enable communication over the existing internet infrastructure. This system utilizes light weight secure CoAP (lwsCoAP) that is designed for secure data transfer using CoAP where the encryption is based on Elliptic Curve Cryptography (ECC) which significantly lowers the required computational effort for data encryption which is essential for the constrained IoT devices such as EB800. This component is also utilized on the server side to enable creation of the secure communication channel between the devices and the rest of the platform.

The cloud platform and associated building blocks enable the core features such as the permanent storage and access to the data (**Data Storage and data access web services** within the Data Server component). Search and discovery of resources and services is performed using the **Resource Directory** (RD) component. **Complex Event Processing and Publish/Subscribe** broker enable detection of complex events from multiple heterogeneous data sources. Once these events are detected, they are forwarded (published) to the users or components that consume them (subscribers). **Calibration** component is very important module in the context of the environmental monitoring sensors as it provides functionality for continuous correction of acquired data using the empirical models derived during the laboratory calibration phase. **Data processing** component is responsible for providing various levels of data analysis, used by the **Visualization Framework** for example (e.g. data interpolation, data averaging, medians, trends etc.). Visualization framework enables the application-level components to display the measured values utilizing set of widgets capable of showing real-time, historical and other statistical data sets. **REP handlers** represent the top-level entry points for accessing the EB800 devices provided that the access is allowed by the authentication and authorisation procedure. **Service provisioning and control** component is responsible for handling creation of various services that can be provisioned on the system. For example, a service can be created that provides temperature measurements every minute which only specific users are allowed to access. **User management** component provides functionality for the creation of users and access rights based on the **access rights rules** defined for the entire platform.

On top of the architecture stack there are **web and mobile applications** that are used to access services provided by the platform. Furthermore, additional web applications are used for the administrative purposes.

5 AR Genie Platform

5.1 AR Genie Platform Overview

The AR Genie platform aims to dramatically simplify development and deployment of AR applications by utilizing pre-defined templates, components and modules enabling creation of cross-platform applications with no programming skills required. The concept is presented in Figure 5 which shows the conventional development of AR applications requiring a high number of resources and tasks, whereas the AP Genie dramatically reduces both of these aspects, and shortens the development time from several months to several days only.

The overall architecture of the AR Genie platform is shown in Figure 6.

The AR Genie platform contains three main building blocks, namely:

- AR Genie Creator
- AR Genie Deploy

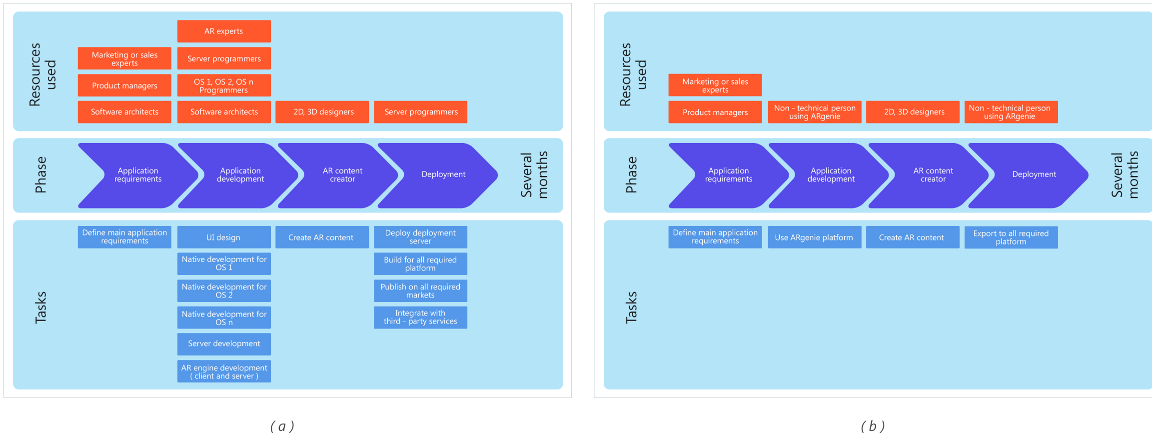


Figure 5: Development of AR applications using (a) conventional process and (b) AR Genie platform

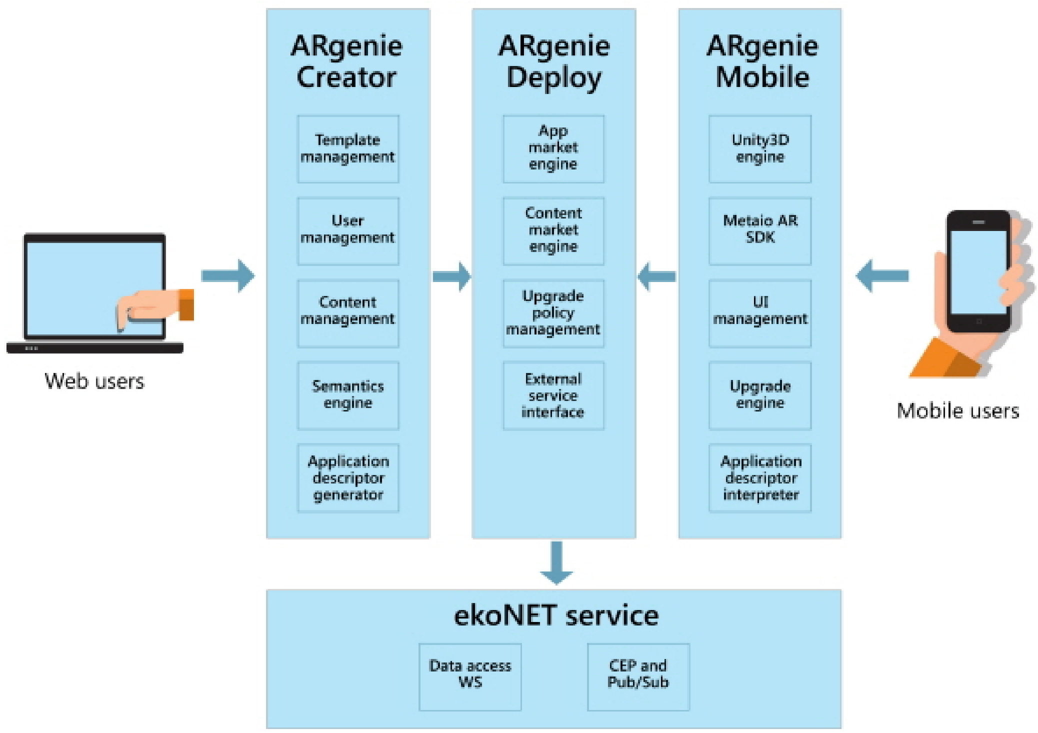


Figure 6: Top-level architecture of AR Genie

- AR Genie Mobile

The *AR Genie Creator* effectively provides SaaS for creation and design of AR applications. It is based around an intuitive User Interface (UI) that enables creation of mobile applications utilizing a set of pre-defined templates that are provided within the platform. It is primarily used by the web users on desktop computers. User is able to select the type of AR markers to be used (location, image or marker-less tracking using SLAM-based technology). Furthermore, users can define the content to be shown once an appropriate marker is detected

Associated building blocks of the AR Genie Creator are shown in Figure 6. Template management component is used to control the available features within each of the templates and provide associated components that are applicable in that context. User management component is used to provide functionality for the provisioning of users and associated access rights according to the selected development package. The content management module is devoted to the handling of all the content used within the platform namely image markers, 2D, 3D models, audio and video files. Many of these components are then transferred to the Content Market engine. The Semantics engine is responsible for providing an appropriate structure that enables creation of the application description that is subsequently used by the mobile application descriptor interpreter.

The AR Genie contains initial set of templates that includes animated books, taking a photo with AR content, treasure hunt game, birthday and Christmas cards. An example of application being created within the AR Genie Creator is shown in Figure 7

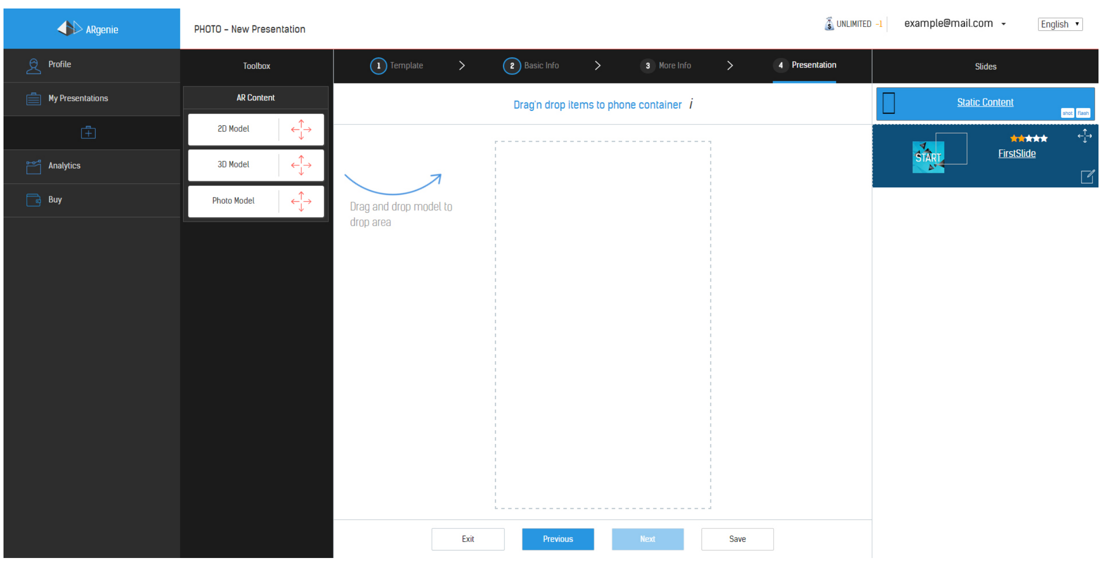


Figure 7: AR Genie Creator portal

AR Genie Deploy is a PaaS providing the cloud infrastructure for the application being executed on the smartphones. The main components are shown in Figure 6. App Market engine enables the users to browse the available applications classified into different categories as being defined during the application design process on the AR Genie Creator portal. This component also provides support during the creation process of the applications so that the created applications are deployed within the AR Genie Deploy infrastructure. The Content Market engine provides the framework for the management of all the media content including the image markers, 2D, 3D assets, sound and video media files etc. The intention is to enable all the content used by the application designers to be made available to the community of developers (if enabled by the content owner). Ultimately, the market will also enable developers and artists to buy and sell the media content. The upgrade policy management provides functionality for the application versioning support so that the developed applications can be upgraded to the latest version and synchronized with already deployed applications on the mobile phones. The External service interface provides support for connecting the applications to the additional services that are outside of the AR Genie Deploy infrastructure. This component is utilized for the integration with the ekoNET IoT service for the environmental monitoring.

AR Genie Mobile is a mobile application available for Android and iOS that communicates with

AR Genie Deploy infrastructure. This mobile application provides functionality that enables execution of designed and developed AR applications within the AR Genie Creator platform. It integrates the Unity3D engine enabling the handling of 3D animations, physics and other features required for the associated AR applications. For the marker detection process, Metaio SDK is utilized [32]. One of the main components is the application description interpreter that inflates the entire application including the media content from the descriptor file. The descriptor files are provided and downloaded from the AR Genie Deploy App Market engine. Once downloaded, the application can be installed or upgraded with the help of Upgrade engine if new version is available. The management of the graphical components that are part of the designed applications are handled by the UI management component

5.2 Integration of AR Genie and IoT ekoNET Service

Integration of the ekoNET service with the AR Genie platform enable utilisations of a real-time environmental data within the AR applications and services designed and deployed on smartphones. The primary purpose of integration is to enhance the ekoNET service with the state-of-the-art immersive user interface providing new ways for data visualization, enabling creation of novel services and products. The principles and methods outlined here can be applied to other IoT services and platforms available.

From the technical point of view, integration of the AR Genie and the ekoNET platforms can be achieved using two main interfaces, namely direct data connection (i.e. using appropriate data access web services) and Publish/Subscribe interface respectively. Both of these methods are commonly available within other IoT platforms and therefore provide a base for the integration with wide range of other IoT services. For the simple use-cases that involve limited number of data streams and trivial conditions (e.g. temperature is above or below a certain threshold), utilizing direct data connection interface would be sufficient. In this case, a raw data stream is accessed and processed within the data processing component located in the AP Genie Deploy infrastructure. The data processing component is responsible for creating events when required conditions are met which are then forwarded to the subscribed mobile clients. The application executed on the mobile client side processes these events and performs certain actions in the AR context, for example adjusting the content being shown or displaying the appropriate messages.

In the situations where more complex events are to be detected, for example from a number of heterogeneous data streams originated from a large number of sensors, actuators and other streams, Publish/Subscribe interface is more suitable in the context of integration with the AR Genie platform. This situation would be, for example, if multiple ekoNET devices are being utilized taking into account multiple sensors. The integration in this case involves connecting the AR Genie Deploy data processing component to the Publish/Subscribe broker within the ekoNET cloud infrastructure specifying the conditions that need to be detected. The Complex Event Processing component located within the ekoNET cloud infrastructure is responsible for the detection of complex events from multiple data streams and forwarding them to the Publish/Subscribe broker. The broker then forwards the notifications to the Data Processing component within AP Genie Deploy which subsequently notifies appropriate mobile clients about the detected event

6 IoT Service with AR Use Case - ARvatar Serious Game

IoT services can be enriched in various ways, but AR offers engaging and novel approach in data presentation. In this way users will be more attracted to the particular IoT services, which presents a useful content in more appealing way. The proposed concept is presented through a simple use case, AR based game using IoT service. The ARvatar game is designed and deployed on Android and iOS devices in order to demonstrate the capabilities of integration of AR Genie and ekoNET environmental monitoring service. The primary purpose of the game is to present the methodology for the visualization of environmental data using the AR technology in a fun and at same time educational way, hoping to raise awareness of the air pollution issues.

6.1 Implementation of ARvatar Game in AR Genie Framework

The game is focused around avatar that the user selects at the start of the game. The avatar can be visualised through the AR view once the appropriate markers are detected. The appearance of the avatar is influenced by the information received from the ekoNET service in real-time. Initially, temperature and CO2 measurements are taken into the account. If the temperature is below the specified lower threshold the avatar is displayed with a scarf and a hat. If the temperature is between a lower and an upper threshold, the avatar is displayed in a long sleeved shirt. Finally, if the temperature is above the upper threshold, the avatar is displayed in a t-shirt and with the sun-glasses. In terms of the CO2 measurements, the avatar responds to the high and low levels of measured CO2 concentration in the air. If the measured concentration is above the specified threshold, the avatar is displayed with the gas mask. Once the avatar is visualised, the player can guess the real values of temperature and CO2 concentration which are then compared with the true values and the score is determined. The closer the guess is, the more points are awarded. The score is then forwarded to the AR Genie Deploy platform and accumulated with any previous score. Furthermore, a high score leader board visible to all players is generated.

The complete game development process is carried out using the AR Genie Creator cloud service (see Figure 8).

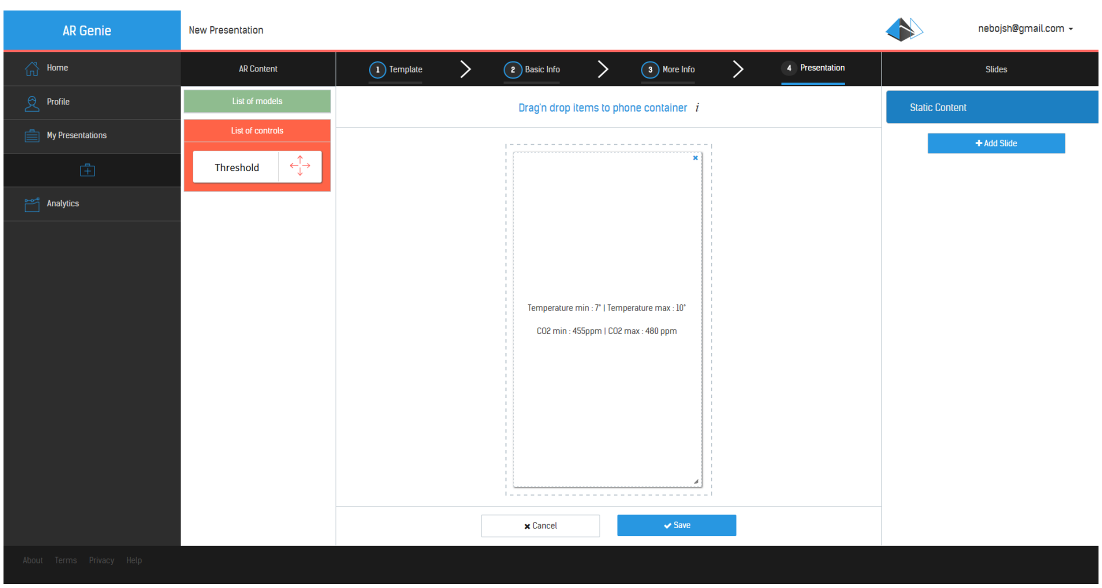


Figure 8: AR Genie Creator portal used to create ARvatar game

Appropriate markers and 3D models are uploaded and the respective slides are created. The slides in the AR Genie context relate to the AR scenes or actions that occur triggered by the detection of a particular marker. The markers can be represented by images, location or they could be the global planes detected (i.e. table top, pavement, floor tiles etc.) utilizing the SLAM technology. Furthermore, desired events are defined, tracked and utilized within the game executed on the smartphone. The events include the temperature value crossing the specified lower and upper temperature thresholds as well as the CO2 concentration crossing the CO2 threshold. Additionally, an ekoNET device is selected from the drop-down list based on the location. The device can be changed within the ARvatar game as well enabling

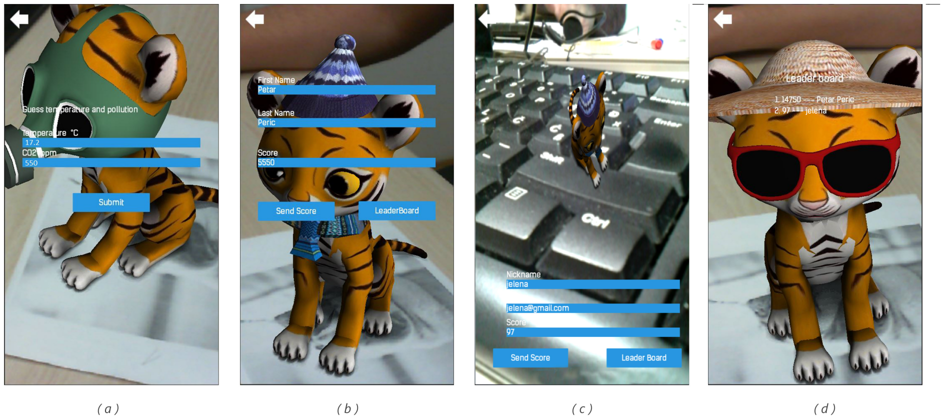


Figure 9: Mobile application look and feel. (a) displaying AR content on detected image marker and user guesses the temperature and CO2 values, (b) user receives the score and posts it to the leaderboard, (c) user receives the score and posts it to the leaderboard, (d) leaderboard displayed

the end users to see the environmental conditions at different locations. Once the design is complete, the application is published and ready to be executed within the AR Genie mobile framework. The ARvatar application look and feel is shown in Figure 9 indicating different steps within the game. As it can be seen an animated 3D model of a small tiger is used as the basis for the avatar.

6.2 Testing and Evaluation of AR Genie and ARvatar Game

This Section provides details on the initial testing and evaluation of the AR Genie and the ARvatar game conducted with 23 end users in a controlled environment. The purpose of the study was to determine the end user's opinion of the usefulness of such tools and mechanisms in building the AR applications and promoting environmental issues. Two experiments were designed where the users first created the ARvatar game using the AR Genie platform and then played the game. The users were then asked to complete two short surveys which were designed to capture their opinions based on the following questions:

- Does ARTool simplify the development of AR applications?
- Is the usage of ARTool intuitive enough?
- Does ARTool provide sufficient amount of features for the development of AR applications?
- Would the non-technical persons be able use ARTool?
- What is the performance of AR applications on the mobile platform being used?
- Is ARvatar game educational and entertaining?
- Is ARvatar game simple and intuitive to use?
- Does ARvatar game promote environmental issues?
- Does ARvatar game provide a basis for further development within the community?
- Does ARvatar game perform well on the mobile platform being used?

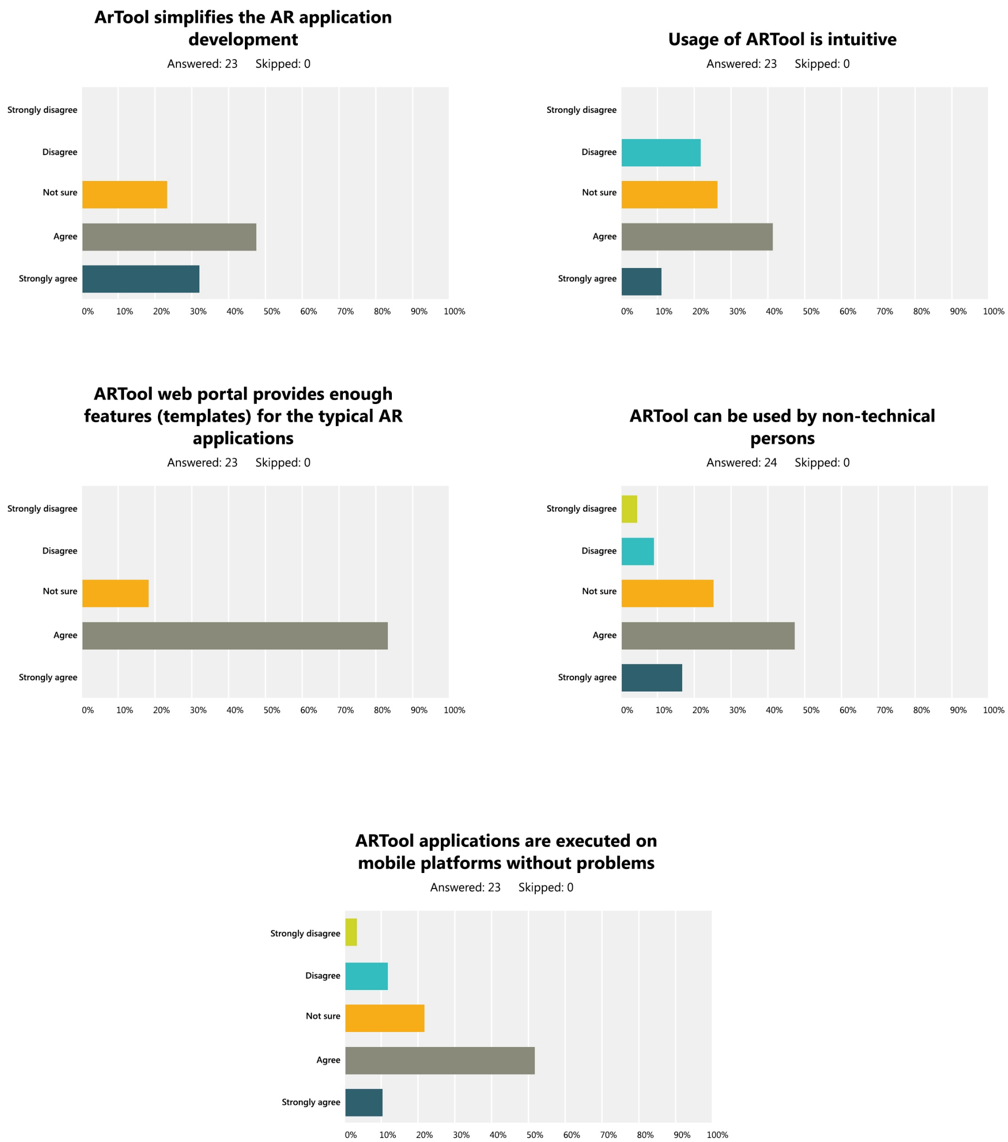


Figure 10: Responses to the survey related to AR Genie (ARTool)

The available answers were provided in the form of multiple choices (Strongly disagree, Disagree, Not sure, Agree, Strongly agree). Furthermore, the surveys allowed the users to leave the comments with the suggestions on how to improve the covered aspects of both AR Genie and ARvatar.

The selected group of end users have not seen AR Genie and ARvatar game before. The initial group was selected from the DunavNET employees, most of them people with technical skills (20 of them) but also from the administrative department (3 of them). Later evaluation will involve external users and groups. The end users were split in groups of four with one assistant being present during the experiments. Each experiment cycle was lasting for 35 minutes. The AR Genie platform was hosted on the DunavNET cloud server. The AR Genie Creator application was used from the standard PCs located at the DunavNET premises. Furthermore, various mobile devices were utilized to execute the ARvatar game (Samsung s3 mini, Toshiba at300se, Alcatel M Pop, Samsung Galaxy s2, etc.)

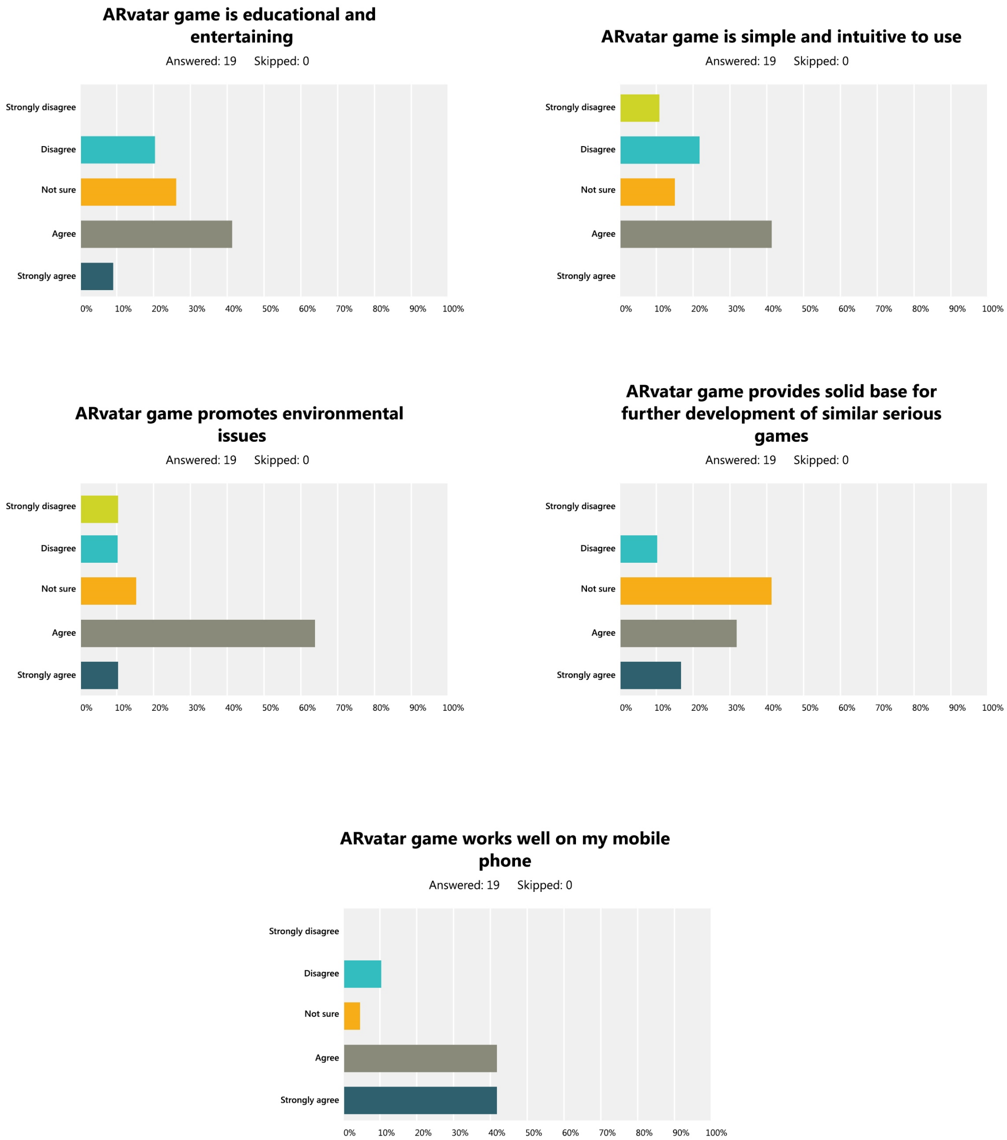


Figure 11: Responses to the survey related to ARvatar game

All mobile devices were connected to the network via WiFi. The users were free to opt-out from the experiment. The surveys were anonymous and no personal information was neither being collected nor stored. The data collection involved the answers to the presented questions via web-based survey.

Feedback received from the two surveys are shown in Figures 10 and 11. From the collected responses it is possible to conclude that the initial version of AR Genie shows positive trend in all five categories covered by the five questions presented in the survey, namely simplicity for AR development, usability, available features and usage simplicity. Received feedback and associated comments and suggestions will be used to improve the AR Genie in the subsequent releases. Main comments indicate that more tutorials are required and more templates need to be available in the future. Additionally, some technical issues have been identified and these will be addressed in the next release. In terms of the ARvatar game, the response is slightly worse than for the ARTool. The survey indicates that additional explanation is required in order to present the main concept of the game reflected by the number of responses in “Not sure” category. Short story will be provided and a simple tutorial in order to address this issue. The main indicator which is related to the promotion of the environmental issues shows that the participants agree that ARvatar game meets this aim. Also, the survey will be extended to other user groups with people who are not technically skilled, and more or less are familiar with environmental issues in order to get their views as well.

7 Conclusions

This paper presents a novel application of AR and serious gaming concepts within IoT domain. The overall aim was to demonstrate use of the AR technology, which by itself provides more interactive and engaging way to present digital information in the real world, within existing IoT services and solutions creating a new dimension in connecting people with things around them. This concept can be used to provide rich and immersive user experience for promotion of various important issues and concepts, in this case the air quality and meteorological parameters.

Architectural concepts and approaches on integration of the AR and IoT platforms have been addressed and presented using a real scenario addressing the AR Genie and the ekoNET ARM. It has been demonstrated that AR with IoT applications can be created without any technical skills required through the use of AR Genie platform which dramatically simplifies the creation of complex and technically demanding applications combining two domains such as IoT and AR. This enables rapid development of serious games such as ARvatar which combines environmental monitoring ekoNET service based on the low-cost electrochemical gas sensors within the AR Genie platform.

End-user evaluation of the first release of the ARvatar game shows that the majority of users find that the game promotes environmental issues and although more people thought that the game is educational and entertaining, there was a mixed response in the sense of how simple and intuitive the game is. Therefore, subsequent releases of the game will take these findings into account and introduce more educational content and different ways of data presentation through AR will be explored and continuously tested

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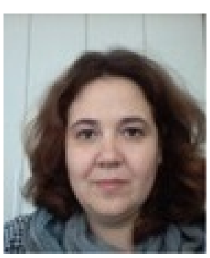
Author Biography

Boris Pokrić holds a PhD degree in the area of artificial intelligence and machine vision. Over the last nine years Dr. Boris Pokrić has been acting as a technical director and co-founder of DunavNET. His interests are in the areas of Augmented Reality, future internet and IoT, and he is engaged across multiple activities within the company such as business development, product management and system architecture. The company is now established with a range of commercial products in the IoT, AR and mCommerce domain.

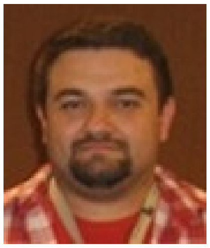
Srđjan Krčo holds a PhD degree in the field of mobile health monitoring. He is co-founder of DunavNET where he currently holds CEO position. Srdjan was employed at Ericsson where he managed a number of product development and research projects focusing on WCDMA, M2M and Internet of Things. He has participated in a number of FP7 R&D projects and is actively involved in the International IoT Forum. He has published more than 50 papers and over 10 patents. In 2007 he received the Innovation engineer of the Year Award in Ireland from the Institute of Engineers of Ireland.

Dejan Drajić holds a PhD degree in the area of chip equalization in advanced receivers for WCDMA downlink. His main research interests are future mobile networks (LTE and beyond LTE), M2M, IMS (IP Multimedia subsystems) and Internet of Things. From 2010 he is involved in FP7 projects related to these areas. Dejan has published more than 30 peer reviewed papers as well as 5 chapters in Monographs. He is IEEE member and reviewer for some journals and conferences (Transaction on Emerging Telecommunications, Ad Hoc & Sensor Wireless Networks).



Maja Pokrić holds a PhD degree in the area of data modelling in computer vision. Maja has worked on number of international projects in the areas of X-ray scientific imaging, MRI/CT medical imaging, video quality assessment as well as in patent technical analysis and creation process. Recently her interest lie in the area of Internet of Things (IoT) as well as remote sensing. She has written over 30 conference and journal publications, and is activly involved in various FP7 projects in the area of IoT.

Vladimir Rajs received the M.Sc. degree in Electrical Engineering and Computer Science from Faculty of Technical Sciences, University of Novi Sad, Serbia, in 2007. He is Ph.D. student and Assistant of profesor at Faculty of Technical Sciences in the area of Applied Electronics and has research experiences in the field of Application of Electronics in Environmental Protection. Vladimir has published more than 30 papers in the area related to his research.



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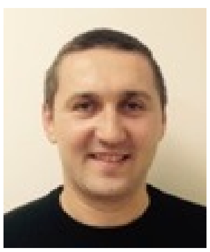

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