GIS SDKs dynamics echoed by social requirements transformations

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***Abstract*—The aim of this paper is to describe the evolution of GIS applications development process, based on the SDKs transformations, especially by considering the ESRI ArcGIS development platform. On the one hand, this study relies on our previous experience in GIS software engineering; on the other hand, it reflects the features and particularities of the projects we conducted within the bachelor and master's theses of our students. Further comments are being made, regarding the transformation of traditional desktop applications to gain contextual recommendation functionalities as well as their reengineering towards mobility. We furthermore intend to determine whether the integration of Virtual and Mixed Reality in this typology of applications is feasible and to anticipate the usefulness for communities of users grouped either by their geographical location or by their common interests.**

***Keywords*— GIS; Virtual reality; Mixed Reality; Software Engineering**

I. INTRODUCTION

The process of GIS applications development has been committed at first to desktop users, interacting with rigid and inflexible applications, with some basic functionalities and at the same time demanding higher computing resources for basic operations. As time passed by, the need for more advanced features, such as in-place editing, georeferencing, addition of new layers in a more dynamic way as well as the elaboration of more complex operation needed in the decision-making process significantly contributed to the appearance and further to the evolution of software development platforms such as ArcObjects. At the same time, documentation has become more and more relevant and accessible to the GIS applications developer community. This led to the large-scale distribution of mapping application with geo referencing functionalities and many programmers have begun to be interested about the GIS applications development.

While desktop GIS remained as a solid foundation for future transformations and updates in functionalities, developers started focusing on adapting the applications to Web and distributed environments, especially by considering the N-tier architecture. These premises considerably contributed to the creation of dependable SDKs, among which we may mention the .NET Framework extensions for ArcGIS, as well as various APIs and services, included in many types of applications.

According to [1] ArcObjects are a set of C++ based components that were platform independent. They provided to developers the possibilities of working with thin and thick clients and on the Web, for creating software that uses maps presentation, geographic and spatial data analysis. As professors, we became interested about these technologies and our students in Computer Science have chosen GIS based applications as subjects for their graduation projects. A set of theses and projects have been built by taking into consideration the evolution in time of different types of application platforms, the dynamics of knowledge to which the development technologies correspond.

In these types of projects, the ArcObjects APIs for C++, .NET and JAVA have been used within both the teaching and the project development processes. Over time, both GIS application development and the platforms, which host them, have evolved and radically transformed, so that in about 10 years' time applications became widespread on virtually unlimited number of mobile devices and unlimited possibilities of further developments.

The ArcObjects have been greatly used in our projects, at first for the construction of traditional desktop applications, which were further transformed through reengineering to obtain novel and dependable web and mobile applications with higher level of accuracy, correctness and portability. For each of these quality characteristics, metrics have been defined and implemented. The process of testing as well as the processes of adaptive and corrective maintenance restructured and improved the quality of the GIS applications. The existing software libraries proved to be reliable for further developments with minimal effort of transformation and maintenance. However, the transition from desktop mapping applications to mobile-enabled context aware recommender systems presumed large efforts of development and consequently the only dependable and efficient solution has been identified as reengineering.

II. CONTEXT-AWARE RISK AVOIDANCE RECOMMENDER SYSTEMS BASED ON GIS INFORMATION PROCESSING

Given our experience with the .NET platform and the Visual C # .NET programming language, as well as the outstanding quality and stability in time of the C# applications, we developed apps for smart devices in a very straightforward way, by means of ArcGIS SDKs and development libraries. The examples delivered were very informative and trustworthy serving for the advancing in the engineering of new apps. We extended our area of knowledge by developing applications based on JAVA programming language and on the corresponding ArcGIS Android SDK.

In [2] we provided a general framework for the development of risk management through mobile GIS recommender applications. An important purpose of the paper was the improvement of the process of natural and anthropic risks awareness for the identified Romanian communities. The software application prototype informs the communities exposed to natural, environmental and social risks in well-defined geographic areas. In this way, we have modelled the requirements and went forward with the engineering process based on models and patterns, on which the documentation libraries proved to be very helpful for the construction of GIS apps. The aim was to obtain context-based recommendations, based on collaborative filtering, and these recommendations to be further tested on specific categories of users.

Based on ESRI ArcGIS framework a mobile recommender GIS application was developed by means of ArcObjects, Web GIS and ArcGIS extensions for Silverlight.

Owing to the evolution in requirements and in technologies and to the retreat of the Silverlight extensions of ArcGIS, the following version of the application has been developed in JAVA, for Android achieving the mobility feature [18]. In parallel, a C# application has been developed based on XAML and ArcGIS.NET SDK [5]. Nowadays, the development effort is significantly reduced because of Xamarin and the Xamarin.Android, Xamarin.iOS, and Xamarin.Forms cross-platform applications, which also implement the ArcGIS functionalities.

The functional specifications were defined by means of specialized modelling languages, which integrate patterns, templates and diagrams for the functional analysis process. It is very important to make the distinction between the different categories of actors involved [2] in the use of mobile GIS risk recommender system. For each categories of users, specific roles have been defined. These roles clearly separate the actions that users might take for the notification or distribution of information related to the identified risks.

The local community members have been identified as the most important category of users, which were directly exposed to the risks and simultaneously the ones which have the possibility of offering help to the authorities in case of natural disasters in certain exposed areas within a specific region.

Consequently, the local authorities were in the position to collect information from the citizens by means of mobile devices and specialized software and to send them elaborated recommendations based on contextual information and collaborative filtering. The regional institutions were also identified as important actors in the analysis. In case of necessity, they had the possibility to get informed by the other categories of actors about the specificity of any risk event, a natural disaster or an anthropic risk in a precise geographical location and with prediction facilities for any further resource allocation to minimize the risks effects.

One of the most important and dependable source of information consisted of the actors from the field, belonging to the local authorities. With their help, the information provided by the citizens could be verified and subjected to collaborative filtering, as shown in [3],[4], and then sent by social media channels on the mobile devices of the users.

The data obtained from the field have been included on the geospatial databases, with dedicated layers for each typology of risks. The geospatial databases had the possibility of being queried and filtered in correspondence with the users' need of information related to specific areas of interest. The administration of these type of databases was challenging from both computing resources and the need of specialized personnel, because of their size complexity and also because of the measures taken under the supervision of authorities and under authorization.

Harmonizing the evolution SDKs to the dynamics of GIS applications requirements was accelerated by the social demand. Applications became more flexible, mobile, user friendly and backing the process of automatic decisions making.

The dynamics of knowledge and software have placed various types of actors and actions in very complex scenarios. In such contexts, collaboration was greatly reflected by specialized modelling languages, such as UML and presumed the use of the subsequent object modelling methodologies.

We obtained the model that has further been transformed into classes of objects and relational databases, included AI and the use of sensors. Adding the mobility characteristic has proved to be quite straightforward, based on the libraries and APIs that have been provided by ArcGIS SDKs.

Creating contextual recommendations presumed the deep study of the behaviour of each actor, and the way it got information from the system as well as the steps needed to be taken for achieving its specific objective. This approach generated complex use cases for each role, which further needed to be simplified and reduced to essential. The architecture prototype of the context aware GIS based risk recommender had finally become fair in terms of size and computing capabilities. Geolocation and georeferencing were implemented using mapping engines, mobile devices and tracking devices.

A particularly important topic in the development of GIS applications is represented using mobile device sensors. Usually, GPS or A-GPS, cameras, accelerometers and gyroscopes are needed for positioning the device within the geographical area. The functionalities of the sensors are usually implemented by corresponding classes and objects provided by ArcGIS SDK for mobile devices and for the web. The manufacturers of the devices also provide dependable classes and objects for working with the sensors, meaning that the developer could decide on which objects to use. Xamarin environment, which allows the development of cross-platform applications development on C# and Visual Studio, as well as the previous mobile apps SDKs discussed in [2], [5] and [6] offer specialized classes, objects and functionalities for working with the georeferencing and routing processes by means of the device sensors.

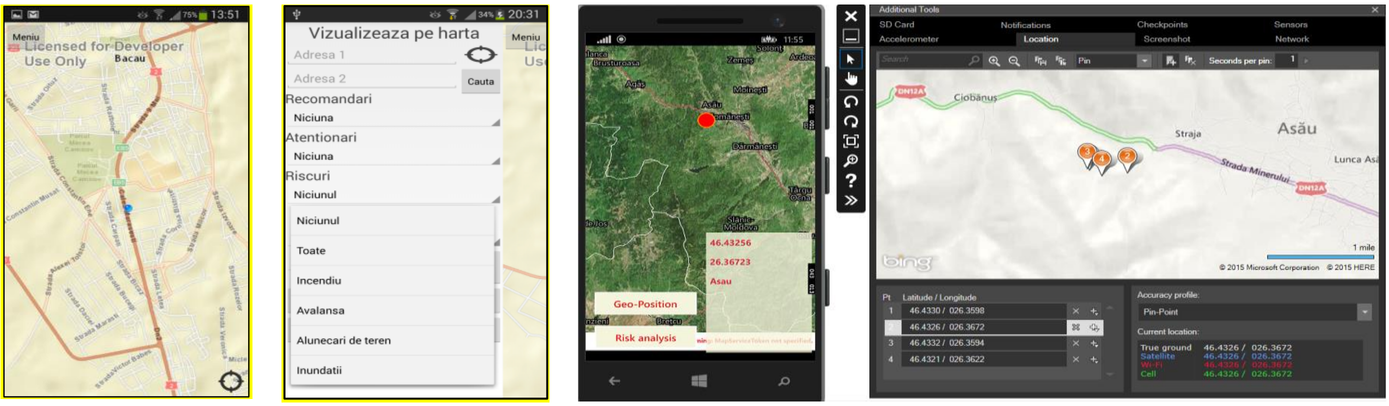

Fig. 1. Android and Windows Phone GIS applications for risk recommandations

Figure 1 shows the user interface of two applications for risk awareness and recommendations, for Android and Windows Phone. The users may search for information specific to certain geographic areas and act accordingly.

They receive notification from the authorities and in case of risk occurrence, such as flooding, landslides, fire or any other accident they may either avoid or offer their help if need be.

Further processing implies data filtering and it ensures that the appropriate information is given to a community of users who have common characteristics and should get informed about a common phenomenon, which applies to them. In this situation, the recommendations appear as objects generated by means of the SDK taking the shape of particular messages sent to the users.

III. Further Advances in GIS Software Development – Virtual, Augmented and Mixed Reality Integration

A variety of strategies may be used for integrating GIS with virtual, augmented, or mixed reality. These strategies can be viewed from several perspectives: *A.* the technical or programmer's perspective; *B.* the functional or user's perspective, and *C.* the conceptual perspective.

A. Technical perspective

In literature, we can find two methods to get 3D virtual reality in the area of GIS. One approach is to use 2D professional platform in which we may consider as an example the ArcGIS software, used to obtain virtual reality. The other approach is to use a 3D or 2.5D software as a platform for development, such as the Skyline software and Unity3D platform [7].

In [8] an application called GeoVR was developed, using the client - server architecture, that successfully created interactive 3D scene and virtual reality modelling language - VRML. This model started from 2D spatial data by use of GIS and HTML programming.

In order to create the 3D scenes the users have to provide a set of properties and through Avenue programming and the use of ArcView Internet Map Server and ArcView 3D Analyst software. These properties are processed in order to generate the 3D scene. Based on the scene the VRML model is created and sent to the specific VRML based browser to be displayed for navigation.

By using a specific method, the authors have shown that the 2D GIS data can be automatically transformed into a VRML model. They also proved that 3D GIS can be enabled for web browsers. By these means, the geoscientists will have the opportunity to build applications that combine virtual reality and spatial data, gathered by 2D GIS tools.

Three types of visualizations have been created in earlier times, according to [9], to support 3D GIS interaction with the environment of virtual reality. These types are the plan view, the model view and the worldview. These kinds of functions implemented in order to manipulate, model and analyse the 2D data.
Novel approaches gained the power to build user immersive experiences. They offer the possibility of using computer vision by dedicated devices and headsets to get in a transformed 3D environment.

B. User's perspective

Users explore the virtual environment and ask for information according to their objectives and the existing points of interest from the GIS database. The possibilities to run queries to the GIS database in a more intelligent way and to access the more advanced GIS functionalities. The possibilities have been limited, until the new AR/VR devices and headsets entered the market.

The immersive technologies adapt the environment to the actual physical space, transforming it into a virtual environment. The users have to easily understand and navigate in the 3D setting, by intuitive interfaces and simple gestures and motions controlled by sensors. In [10] well-known GIS functionalities have been analysed, such as the 3D real-time simulations and remote sensing. Perhaps in industries such as the automotive certain benefits should be obtained by using this technology.

C. The conceptual perspective of integrating GIS with VR/AR

The answer seems to depend on the domain of activity, in relation to the objectives defined. In activities such as environmental modelling, the analysis and manipulation of the virtual reality data is displayed in an exploratory way. The GIS has the main role in this situation. For architectural modelling and urban planning virtual reality plays the main role, as enriched visual communication is usually involved in such applications [11].

Integrating virtual environment and GIS for 3D virtual city development and urban planning is analysed in [12]. A GIS-based 4D visualization and simulation system with military applications [13] provide a virtual environment for predicting and tracking moving targets. It also envisages the probable future movement of multiple ground targets based on the comprehensive analysis of geographical location, terrain, weather, vehicle movement characteristics and vehicle tactics. The integration of 3D Visualization and GIS in Education is tackled in [14] while application of augmented reality GIS in architecture is discussed in [15].

Nowadays, it seems that the IT&C sector is about to bring new opportunities regarding the perspectives discussed in this section. With the release of mainstream immersive VR hardware gear by major players, covering a wide range of prices, levels of complexity and functionalities. More mature and accessible mobile and non-mobile VR/AR+GIS applications and devices will enter the market [16].

Microsoft launched the Windows Mixed Reality platform at the IGNITE 2017 event [17], which we believe that could transfer the technology to a new generation of recommender systems. Users are included in virtual reality scenarios in which they directly interact with the environment and get real-time information, so as to be able to make the best decisions, to act effectively, and to elaborate activities by modelling the environment according to their objectives.

IV. CONCLUSIONS

This paper briefly describes the results we obtained in the development of GIS applications while at the same time the platforms and the SDKs on which the applications have been developed continuously evolved along with the social and economic requirements. In the first stage, we described the origin of ArcObjects and the features and functionalities that ArcObjects offered for traditional desktop applications. Further transformations were applied to the applications in order to evolve to mobile and distributed environments and to become available for larger categories of users. The GIS applications have been enriched with collaborative and context aware recommendations functionalities, reflecting their dynamics along with the evolution of the social requirements. Finally, we tackled the future advances of GIS applications and the possibility of integrating virtual and mixed reality from three perspectives, the perspective of software developers, the functional perspective and the conceptual perspective. This approach could become efficient and productive in the software engineering process and could lead to the construction of higher quality and accuracy in the elaboration of recommendations and the making of dependable decisions.

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