UNIVERSITY "ST. KLIMENT OHRIDSKI"
- BITOLA

FACULTY OD INFORMATION AND COMMUNICATION
TECHNOLOGIES BITOLA

Blagoj Nenovski

APPLICATION OF AUGMENTED REALITY FOR TIME RELATED SPATIAL EXPLORATION

AUTOSUMARY OF THE DOCTORAL THESIS

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MEMBERS OF THE BOARD FOR EVALUATION OF THE DOCTORAL THESIS:

IGOR NEDELKOVSKI, Ph. D (Mentor)
FULL PROFESSOR
FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGIES
UNIVERSITY “ST. KLIMENT OHRIDSKI” – BITOLA

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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGIES
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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGIES
UNIVERSITY “ST. KLIMENT OHRIDSKI” – BITOLA

Gorgi Manceski, Ph. D (Member)
FULL PROFESSOR
FACULTY OF ECONOMICS
UNIVERSITY “ST. KLIMENT OHRIDSKI” – BITOLA

In recent times we can notice the overall attention from companies, developers and media shifting from virtual to augmented reality. That means that many more new and existing companies will focus on hardware and software augmented reality solutions.

At first, most of the solutions were of a scientific character or were offered to enterprises like manufacturing or the military industry. The rapid growth of smart phones and their components enabled for new and innovative ways to bring augmented reality to end users.

There are many categories that can implement augmented reality solutions such as displaying additional data, product visualization, entertainment, marketing, military usage, medicine, industrial design, tourism and education.

The greatest usage of augmented reality with the regular users can be seen by games and social media platforms in the form of camera filters or effects.

This thesis analyzes the hardware and software offerings and with choosing the best combination develops a platform for spatial exploration with adding the time dimension.

There are a few applications available but all of them are limited in the amount of available data and are usually focused on one or few objects. Our goal is to create a platform that will be available to as many users as possible and that it will offer the users the ability to add and manage various multimedia experiences. This includes the display of text, picture, video, 3D model and the reproduction of sound representing the objects past or possible future.

The platform includes a smart phone application for recognizing the objects and displaying the multimedia content and a server for adding, storing, managing, filtering and delivering the content to the user’s phone. During the development of the platform all of the focus was placed on making the entire process automate as possible so the end result will be a system easy enough to be used by everyday users.

PUBLISHED PAPERS RELATED TO THE RESEARCH

[1] Nenovski, B., & Nedelkovski, I. (2018). Defining a feature-rich end-to-end augmented reality platform for spatial exploration. *PROCEEDINGS OF THE 8Th INTERNATIONAL CONFERENCE ON APPLIED INTERNET AND INFORMATION TECHNOLOGIES*. doi: 10.20544/aiit2018.p22

[2] Nenovski, B., & Nedelkovski, I. (2019). Recognizing and tracking outdoor objects by using APToolKit markers. International Journal of Computer Science & Information Technology (IJCSIT) Vol 11, No 6, December 2019. DOI: 10.5121/ijcsit.2019.11603

[3] Nenovski, B. (2019). Augmented reality hardware in the form of smart glasses and HMD devices. TEMEL-ij Vol.3.Iss.2. pages 6–13. ISSN 2545 – 4390

[4] Nenovski, B. (2019). The augmented reality pivot from Tango to ARKit and ARCore. TEMEL-ij Vol.3.Iss.2. pages 37–45. ISSN 2545 – 4390

Realized study visits of the candidate

I conducted a visit to Universidat Autonoma de Barcelona in the period of 07.05.2018 to 11.05.2018. During the stay i was organized several activities to become familiar with the University and Doctoral Programmes. I was organized welcome meeting where I was presented with the mobility agenda and all the planned events together with a tour around the university. During the stay I conducted meetings with other PhD students with whom we shared experiences and knowledge. I was granted access to the university library and other resources. During my stay I did individual research work on collecting academic papers needed for the thesis.

SUBJECT AND AIM OF THE RESEARCH

The beginning of augmented reality starts with the introduction of a head mounted device by Ivan Sutherland in 1968 that included three dimensional display of an image that responded in correlation the users head movement.

By definition augmented reality combines the real with the virtual world; it enables interaction in real time and is registered in 3D. Together with virtual reality they are part of mixed reality but both are at the end of the spectrum. In virtual reality the entire environment is synthetic and computer generated. In augmented reality digital objects are overlaid on the real world.

At the beginning users experienced augmented reality while being at a fixed location with a head mounted display. The hardware advancement allowed for the next stage: head mounted display connected to a computer usually in the form of a backpack thus allowing movement to the users. The need for a head mounted display was eliminated with the introduction of tablet computers and ultra mobile personal computers.

Today augmented reality can be used in multiple scenarios: displaying additional information, product visualization, entertainment, marketing, military usage, medicine, industrial design, tourism and education. That is why augmented reality is subject of continuous research. My focus in on the application of augmented reality for time related spatial exploration. The research in my thesis covers the theoretical foundations of augmented reality, analysis of the hardware and software state together with choosing the right combination and developing an augmented reality platform that enables for time related spatial exploration.

The rapid growth of smart phones contributed to the state where users on their smart phones have: larger resolution compared to their TV's, faster 4G internet compared to their cable of DSL and better cameras compared to Point & Shoot digital cameras. Having multiple sensors such as GPS, cameras, accelerometer, gyroscope, magnetometer and others, allows for image/environment recognition on a smart phone. A server can process the information's and send multimedia data in the form of an image, text, video, link, audio or 3D object to be displayed on the smart phone's display.

The advancement in smart phone augmented reality allowed for apps to be used in real time by receiving 2D/3D information about the location of the device or a certain object that is being viewed in the camera preview. Information can represent the past form of an object/location (how the object used to look like, what was it used for, historical data etc.), the present (what is the recognized object, what is it used for, what is in the inside of the object) or the future (what is going to be build on the location, how the object will look like etc.).

There is research with applications that are specific to using augmented reality for displaying the past state of objects. This includes historical events, archaeological information and presentation of a cultural and historical legacy correlated to a specific relation. However there is little research that includes the time aspect.

In the thesis I developed a platform that supports various time frames for spatial exploration allowing the users to explore multiple time points both from the past and the future of objects.

The main aim of this research was to study the possibilities offered by the widely available combination of hardware and software and develop an augmented reality solution that enables for time related spatial exploration.

I designed and developed a platform that enables the real world to be augmented via a smart phone by adding: text, links, images, drawings, videos, audios and 3D models. The smart phone app gets the devices location and by using the camera recognizes the objects and adds textual or multimedia data to augment the object. This data can be historical text or multimedia from different points in the past but also data for the planned future usually in the form of 3D models and renders of architectural projects. The recognition of objects is done without using fiducial markers.

To achieve recognition without using fiducial marker we studied the combination of location data and data from the smart phone sensors. Most of the focus was on recognizing the environment (object) via the smart phone’s camera and the display of multimedia in correlation to the objects pose in the field of view.

Specific aims of the research

The specific aims of the research are:

1. Design an augmented reality platform.
2. Study the techniques of locating and filtering data from the device location.
3. Study the techniques and methodology of recognition without using fiducial markers.
4. Develop a methodology to visualize virtual objects in the field of view without using fiducial markers.
5. Develop an interaction technique to allow for time related display of multimedia

The end result of this thesis is a fully fledged platform based on the specific aims of the research that is open to add additional objects to be recognized and multimedia to be displayed.

To accomplish the main and specific aims of the research i reviewed the usage of augmented reality in various categories and the published research and apps together with the available hardware and software. The available solutions were limited in the objects that can be recognized and the data that can be displayed.

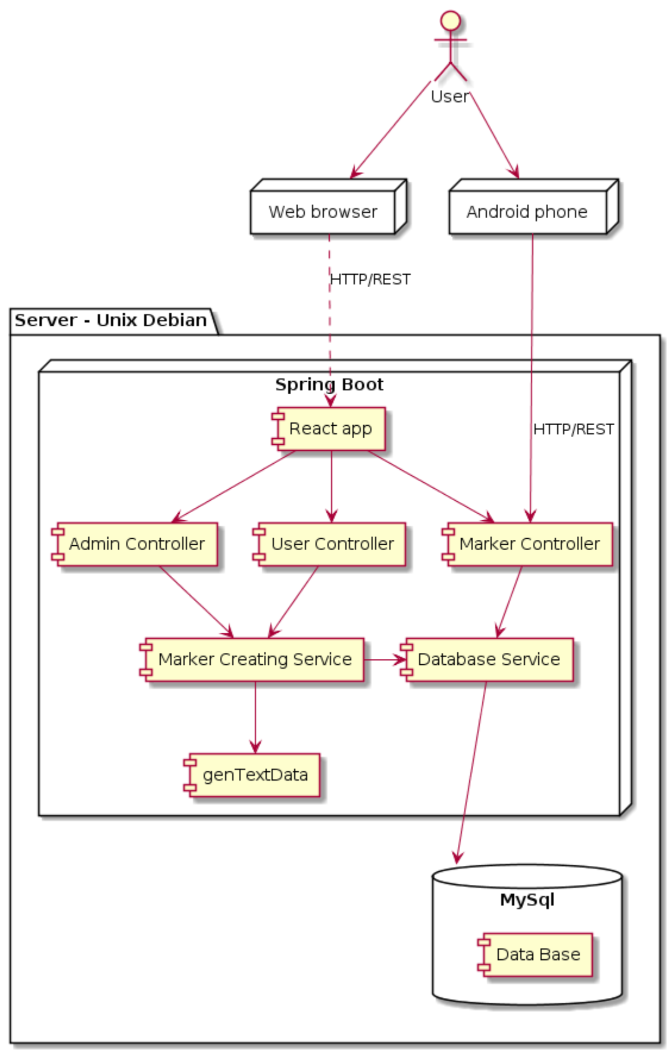
The hardware analysis of the available solutions such as: Glass, Tango, HoloLens, ODG, Avegant and MagicLeap showed that each of the solutions has advantages and weaknesses and are technically different in: whether the device is stand alone or has to be connected to a computer, the field of view, the range etc. Comparing the features to the massive availability of smart phones it was concluded that using a smart phone is the best path to develop the platform.

After choosing smart phones as the hardware for the platform a review and comparative analysis was done between the available SDK's: Vuforia, Kudan, Wikitude, ARToolKit, EasyAR, MAXST and XZIMG as the most popular at the moment. SDK's are different in the type of the license, the supported platforms, the support for smart glasses, support for cloud recognition, 3D recognition, SLAM and UNITY support. ARToolKit was chosen as the SDK to develop because of the fact that it is open source and most used among academia.

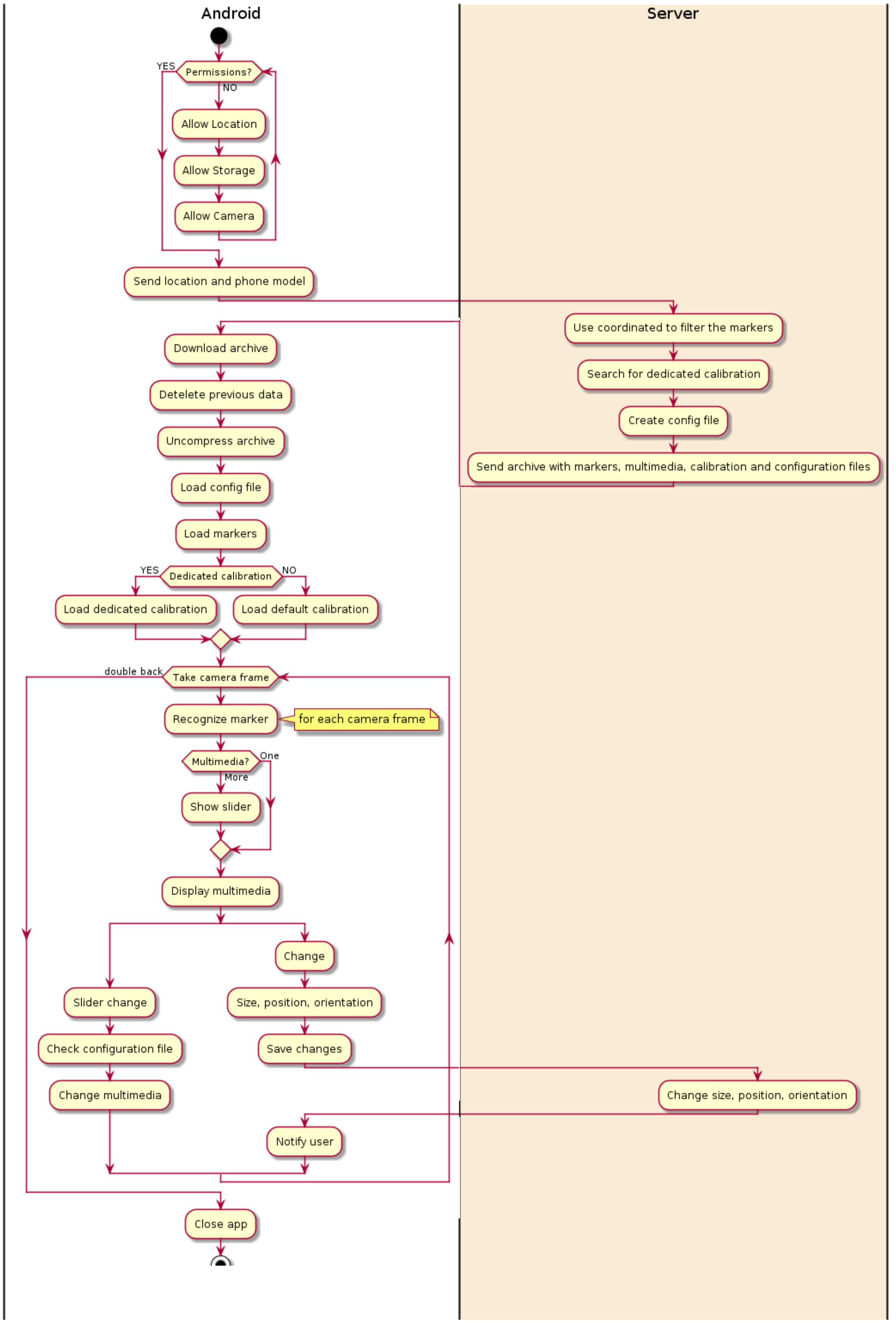
AUGMENTED REALITY PLATFORM FOR TIME RELATED SPATIAL EXPLORATION

The main contribution of the thesis is the development of an augmented reality platform for time related spatial exploration. The platform includes a web server where the markers are created, stored and together with the multimedia data are delivered to an Android app for time related exploration.

The server has user roles that allow marker creation, marker review and marker updates. The updates include adding multimedia and the change of the pose of the multimedia. The admin role can view all of the added markers, can approve/disapprove them and delete the markers.



Platform diagam



Activity diagram

The Android app sends the location and the phone model to the server. Then the server searches the added markers by the coordinated and searched for a dedicated camera calibration.

A configuration file is created from the filtered markers that included the markers available near the user’s location together with multimedia and the pose related to the markers. The markers, multimedia and dedicated calibration (if available) are compressed in an archive and are sent to the device as a single file.

The smart phone deletes previous data, uncompresses the archive and loads the configuration file. The configuration file points to the markers and dedicated calibration file to be loaded.

After loading the markers, the app opens the camera preview and takes the frame to check is any of the markers are being recognized. If a marker is recognized a multimedia specified from the configuration file is loaded. In the case of multiple multimedia, a slider is displayed where the user can change the time points assigned to the multimedia.

The size, position and orientation of displayed multimedia can be changed by the administrator or the creator of the marker. In such cases the changes are sent to the server and then delivered to the next request of the users. The marker check is done for each camera frame until the user exits the app.

Display of an image in augmented reality

MAIN BENEFITS

With the research of the theoretical basis, the hardware and software solutions and with the development of an augmented reality platform for time related spatial exploration the main hypothesis was confirmed:

- Augmented reality technology allows for smart phone recognition of outdoor objects and time related exploration by displaying textual and visual data about the past or the future in real time.

Together with the specific hypothesis:

- By using an array of parameters a simple point of the camera preview toward an outdoor object allows for precise identification of the location and the object.
- Geo-referenced visual augmented data (photo, video, 3D model) can be displayed over the camera preview without using fiducial markers.
- A database of markers and multimedia for augmented purpuses can be developed so users can update with new markers and multimedia.

By researching the possibilities offered by augmented reality from the available combination of hardware and software for a solution that allows time related research, the developed platform fulfils the main and the specific aims. It contains a mobile app to recognize the objects, display multimedia for various time points and is open to update.

The developed augmented reality app can be used in multiple categories including but not limited to:

- Tourism, as a guide for the users and provider of textual and multimedia data for multiple outdoor objects and locations as points of interest.

- Education, by using smart phones on site and in real time, students can view data correlated to the location or the object.

- Archaeology, by using smart phones that allow the reconstruction of archaeological locations on site.

- Urbanism and architecture, by using smart phones on site to display visual data that represent the planned future look of a location or an object.

Display of 3D object in augmented reality

A detailed validation resulted with a specific guidelines for creating the markers and the display of multimedia:

- to achieve good recognition speeds and quality tracking, the objects facade needs to be extracted from the photo prior the marker creation
- resizing the photo allows for better recognition and better tracking
- using a dedicated camera calibration provides much better results compared to the default camera calibration
- using a digital camera does not provide better results when using camera calibration
- if the environment allows the entire object to be seen it is best to use as large range of the facade as possible. Using parts of the facade results in lower tracking quality.
- when creating markers with ARToolKit 5.3 regardless the input for the initializing features the output always contains the same number of initialization features.
- when using a resized photo together with a dedicated camera calibration, the level of tracking features does minimal effect on the tracking quality
- the camera resolution on the Android app is one of the main factors that affect the user experience. Resolutions that have 4:3 aspect ratio enable the best results for recognizing and tracking the markers.

- although using 320x240 as the camera resolution provides the fastest recognition speed, the camera preview does not allow enough details for a quality user experience.

- the total number of markers affects the recognition speed but not the tracking quality

- reducing the quality of the multimedia allows for faster display times for images and 3D objects, but not for audio and video.

- displaying 3D objects takes noticeably more time compared to other multimedia. Reducing the size by reducing the polygon numbers is suggested.

- archiving 3D object results with much smaller file size compared to other multimedia. The archive of 3D object can contain multiple files and the smaller file size of the archive allows for faster upload times.

Structure and content of the Doctoral Thesis

The doctoral thesis is structured in multiple chapters:

Chapter 1 gives a preview in the: subjects of the research, the aim of the research, the hypothesis of the doctoral thesis, the methodology of the research, as well as the results and the benefits of the research of an augmented reality platform for a time related spatial exploration.

Chapter 2 focuses on the history and the evolution of augmented reality, by analyzing the literature and the recent research together with the developed apps as an introduction to the state of augmented reality.

Chapter 3 analyzes the available augmented reality hardware and includes a comparative analysis of specific hardware with the goal of determining the best hardware to be used in the proposed platform.

Chapter 4 reviews the available software needed to develop the augmented reality Android app and include comparative analysis of SDK's.

Chapter 5 based on the conclusions from the previous chapters and the analysis of similar augmented reality apps suggests augmented reality platform for time related spatial exploration by using widely available combination of hardware and software

Chapter 6 details the developed platform and includes the usage, demo and analysis of the potential usage in real world locations by using real data for augmentation

Chapter 7 is focused on validation the developed app by optimizing the marker creation and app parameters and setting together with optimizing multimedia files for better recognition and tracking and better display times.

At the end we have the conclusions from the research, the developed platform and guidelines for feature research.

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