

Virtual Heritage of the Territory: Design and Implementation of Educational Resources in Augmented Reality and Mobile Pedestrian Navigation

Jorge Joo Nagata, José Rafael García-Bermejo Giner, and Fernando Martínez Abad

Abstract—This paper intends to establish the relationship between the heritage content of mobile pedestrian navigation system–augmented reality application and learning processes through mobile devices. In this context, a teaching–learning process will be developed that is linked to urban heritage, determining the educational effectiveness with these tools. The methodological research focuses on two dimensions: 1) technological design of a mobile learning platform and 2) determining educational modes of understanding of the program. A patrimonial thematic unit will result from this design whose significance in mLearning–uLearning processes will be determined, considering the elements of identity and local culture.

Index Terms—Augmented reality, computer-aided instruction, mobile computing, navigation.

I. INTRODUCTION

SIGNIFICANT technological advances in the field of mobile devices (tablets and smartphones) are the incorporation of highly specialized sensors and the ability to capture information from the environment around us. Instruments such as global navigation satellite systems, light and proximity sensors, barometers, gyroscopes, accelerometers and magnetometers have added significant values to these devices, making complex instruments that are within reach of a hand, with simplified interfaces, simple to understand and use [1], providing information that was formerly impossible to obtain without specialized, complex and most often expensive instruments. This processing power and data acquisition has led to the development of techniques such as Geolocation and Augmented Reality in a context of portability and massification, enabling the development of applications and content on different themes, with different objectives and implementation structures.

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Thus, disciplines such as education have been greatly strengthened by the creation of new tools for teaching content and evaluating knowledge. Additionally, new ideas and lines of action were generated, such as Ubiquitous Learning and Mobile Learning (uLearning and mLearning), at the confluent fields of knowledge where there is a clear complementarity of contents, methods and objectives. Thereby, techniques that have been strengthened by technological advances provided by mobile devices are Mobile Pedestrian Navigation Systems (MPNS) and Augmented Reality (AR), allowing the concrete implementation of various contents present in different fields, with consequences in their educational purposes.

The approach of this research is to build a mobile system linked to MPNS and AR modules, participating in a process of educational training (eLearning and mLearning) within the framework of territorial information related to the historical heritage of the city of Salamanca (Spain). The research is contextualized at two important levels:

- Design and development of a mobile MPNS-AR application, defining the architecture, functionality, interface and implementation (Figure 1).
- Operational test on the presentation, understanding and educational effectiveness of the application developed. Thus, a mobile computer system is expected to emerge that allows appropriate content presentation of the historical heritage, framed in eLearning and mLearning processes. Thereby, the objectives arising from these two major areas are:

- 1) *For the Technological Area*: The implementation of the software used in uLearning and mLearning in the context of developing a MPNS-AR application will be discussed. This aims to have a diagnosis of existing softwares, their strengths and weaknesses, in addition to their implementation in formal educational dimensions. The development of an educational module is also proposed through appropriate frameworks of Location, Navigation and AR present in programs for mobile devices, allowing content generation about the historic urban heritage of the city of Salamanca. Additionally, a MPNS-AR application will be implemented, in a

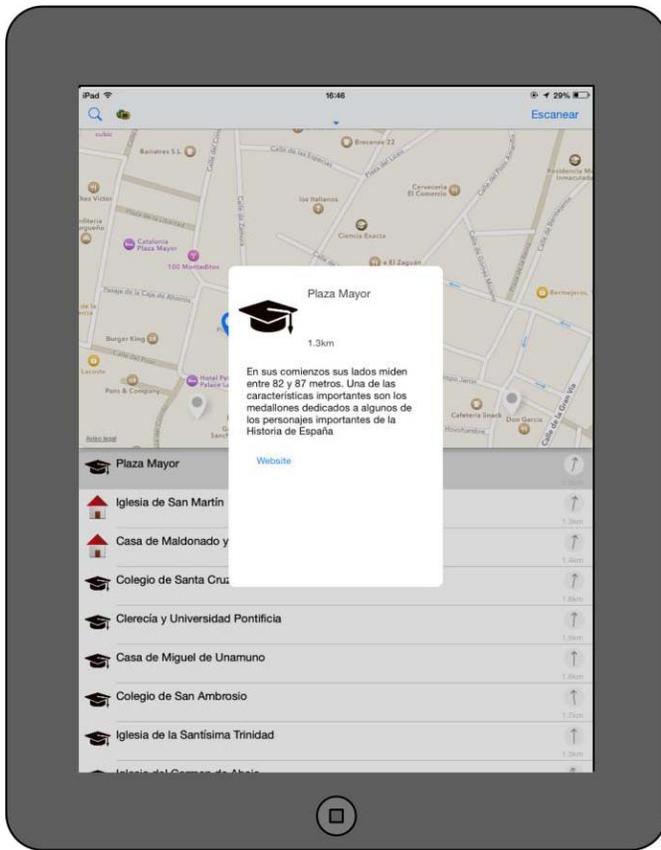


Fig. 1. Interface for the Pedestrian Navigation System.

technological context of architectural and adaptable encapsulated programming through a series of software development frameworks.

- 2) *For the Educational Area:* The lines, features and relevant issues will be determined regarding the development of a MPNS-AR application in the context of uLearning and mLearning. The potential and educational effectiveness of the MPNS-AR application will be determined through the concrete example of the city of Salamanca and its heritage through usability testing and learning assessment tools. Finally, this research aims to determine and contextualize the experiences of students with the proposed MPNS-AR system by identifying relevant issues and key factors resulting from usability in the educational context of uLearning and mLearning.

Due to the quasi-experimental nature of the study, the following hypotheses are proposed:

- The use of tablets with a custom MPNS-AR has a more effective learning process about heritage, compared to traditional methods and teaching tools such as books, maps and direct teaching.
- The mobility provided by devices such as tablets in a MPNS-AR educational context presents more effective learning processes in the fields of uLearning-mLearning, regarding similar teaching situations (eLearning), but

that are established in traditional and formal educational environments (as direct teaching in classrooms).

Through these approaches, the qualities of the elements of hardware, software and content areas will be established and posed for education, generating a ubiquitous system in elements and local heritage processes.

II. THEORETICAL CONTEXT

A. Heritage as Subject in the Context of mLearning and uLearning

From the fields of education, software development and implementation of applications, this process is contextualized by uLearning and mLearning. Thus, an educational context for acquiring knowledge from real-world scenarios, where the heritage in the city of Salamanca is the subject to teach. From the perspective offered by uLearning, the teaching-learning process would be more practical, meaningful and applicable to problem solving, which would maximize the effects of learning in students over other direct teaching scenarios [2], [3]. In this way, the meaning of learning would be deeply rooted in a real situational context—in this case it corresponds to the urban heritage of the city of Salamanca and its local history represented in urban artefacts—, not existing a unique sense of learning, but rather a particular and/or practical context [4]. Additionally, mLearning emphasizes two important principles in education [3]:

- The integration of learning in a practical, mobile, and meaningful context.
- Learning in a collaborative and social scenario, through tools presented in digital and virtual media.

B. Mobile Pedestrian Navigation Systems (MPNS)

A MPNS corresponds to a digital navigation system in a context of representation on a human scale (1:1) assisted by a mobile device (GPS navigators for cars, smart watches, smartphones or tablets), where digital data stored on servers combine maps (digital mapping and spatial data structures), landmarks and points of interest (POI) with a navigation and routing system, which complement and guide the users in their journeys [5]–[8].

These systems are implemented by an independent software that runs on the mobile device and reads data from specialized sensors present in the system (GPS, Wi-Fi, aGPS). Using these instruments and supplemented with multimedia capabilities of mobile systems for the presentation of information, a process of guided navigation begins, displaying data about the places of interest in a background of optimizing the information provided (address, time, distance and complementary data). In this way, with the proper deployment of information it is possible to acquire three spatial levels of knowledge which are synthesized in the mental maps: reference space environment; sequential content and territorial guide of knowledge, through routes and itineraries of journeys; and a contextual survey of knowledge in a general spatial framework [8]–[10].

C. Augmented Reality (AR) in the Process of Ubiquitous Learning and Mobile Learning

AR and data visualization technology allows the interaction of elements of the physical real world with virtual and digital representations in a single interface. This visualization is done by electronic devices, and it is complementary to the actual observation of the phenomena. In this process, the user keeps an implicit control of interactivity of the data represented and visualized by hardware [6], [11]–[14]. This possibility of combining digital virtual objects in a physical-territorial environment has allowed users to visualize abstract concepts, and to experiment phenomena and processes that are impossible to observe from the exclusive domain of the real world [15]–[17]. Currently, AR has more than 70 software development kits (SDK), 14 of which have technology that complements geolocation systems and portability [18]. In specialty stores such as Google Play or iTunes over 500 applications¹ can be found (in categories such as entertainment, advertising, reference, productivity, business, etc. [19], [20]) which incorporate AR for the deployment of thematic information. This is an indicator of the relevance of this technology in the presentation of information in different contexts.

III. MATERIALS AND METHODS

The proposed methodology is framed in a mixed research type (quantitative and qualitative), divided into 4 areas:

- 1) The creation of thematic content through information obtained about the heritage of the city of Salamanca.
- 2) The development of a suitable software for a context of mobility.
- 3) The collection of data and empirical statistical analysis of functionality.
- 4) The determination of levels of usability and software operating in a context of formal learning.

In the processes of creation, generation and implementation of digital contents about heritage for educational purposes, the same stages that are used in software development are required: the capture and collection of initial data; processing, analysis and interpretation of such information; and display of content through interactive visualization that mobile devices provide [21]. From the qualitative perspective, this study is framed by the methodologies of Action Research and Case Study [4], [22], [23], due to the nature of the content and thematic elements present within the framework of study (education in a context of portability, mobility and location). From this perspective, the essential steps of observation of the problem will be developed: interpretation, evaluation or analysis, and problem solving or implementation of improvements. From the quantitative perspective the research is established in a quasi-experimental context [23]–[25] where different dimensions (learning, usability, understanding of phenomena, etc.) will be measured using the software created in previously established groups.

¹Apps for mobiles and tablets until January 2015.

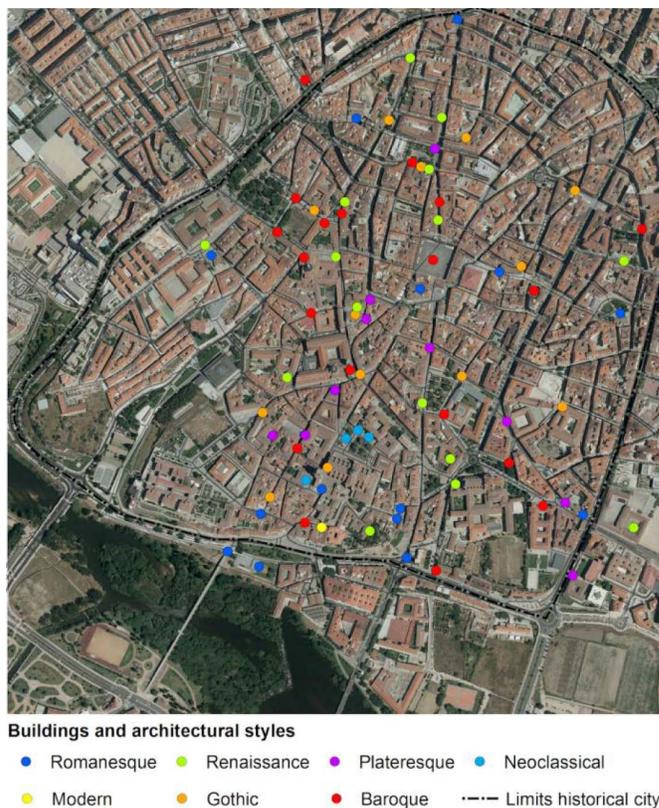


Fig. 2. Study area: historical city center of Salamanca.

A. Contextualization of Heritage Content: The City of Salamanca

For the thematic unit about heritage, the city of Salamanca (Spain) will be used due to its strong character and historical content, which is expressed in the number of buildings and urban landmarks present in the oldest area of the town.

The center has its origins in the early Iron Age, about 2700 years ago [26]. By the year 1102 the first foundations are established for what is known as the modern city, which has important influences from different cultures, with artistic styles of various types [27]. The old city of Salamanca is 125.28 hectares, and was defined as the limit of thematic content, with 72 heritage buildings (Figure 2).

The 72 relevant heritage landmarks within the historic city center have been selected from various sources and authors. These buildings and structures show influences from several architectural styles such as Romanesque, Gothic, Plateresque, Renaissance, Baroque, Neo-Classicism and Modernism [27], [28]. This thematic information is brought together and interrelated, defining possible travel routes taking into account factors such as learning objectives, time and relevance.

B. Stage of Development and Implementation of the MPNS-AR Software

In this phase, the MPNS-AR application will be created and implemented in a portable and mobile environment (tablets).²

²The hardware chosen is iPad tablets by Apple Inc. These devices have displays that range from 7.9 up to 9.7 inches and the software iOS adapts to the requirements of mobility needed for the MPNS-AR software.



Fig. 3. The Cathedral of Salamanca in Augmented Reality.

The contents about the urban heritage of the city will be incorporated by locating places and main iconographic buildings in the city of Salamanca.

Furthermore, the development and implementation of the contents in AR was considered, highlighting the incorporation of multimedia resources with the monumental buildings selected (Figure 3).

It is important to consider that the implementation and design of digital resources for AR for mobile educational settings must keep in mind the principles of integration, ownership, awareness, flexibility and synthesis of thematic content and interfaces that are included in the final development of the program [29], [30]. The MPNS software will be implemented according to the defined territory and the characteristics of the financial information used (dominant architectural styles, historical relevance, significance of the local culture) and considering factors such as geographical proximity, relevance of the phenomena displayed, interaction with other elements within the defined area and pedagogical objectives pursued. This way, a recommendations navigation option is generated to guide the student in the educational process about the heritage of Salamanca. Thus, the system implemented [17]:

- 1) A general territorial vision of the proposed route, which is displayed on a digital map.
- 2) An automatic adaptation of the territorial approach based on the position of the device.
- 3) The possibility of generating different scales of spatial representation according to user requirements.
- 4) The possibility of visualization and query of other urban phenomena represented.

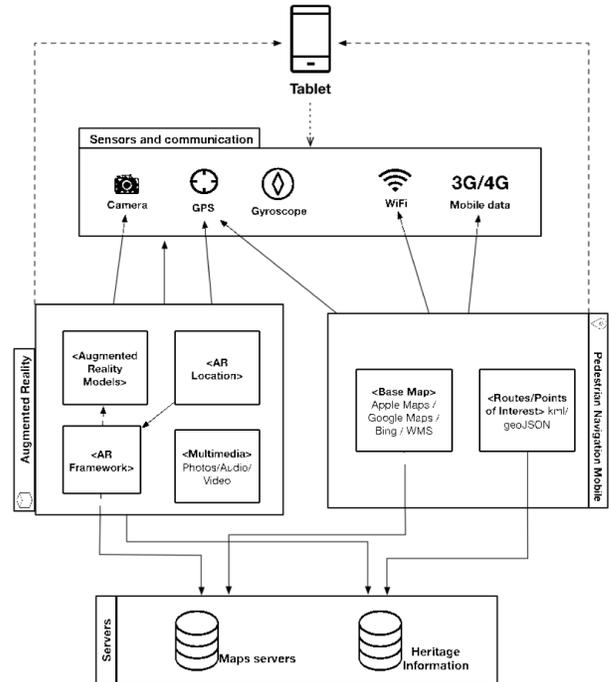


Fig. 4. Diagram of the mobile application where the Pedestrian Navigation System, Augmented Reality and information stored on servers are deployed.

Such implementations could have implications in the students' understanding of the spatial information and the way that the learning process is developed in the field of navigation and territorial contextualization of phenomena mediated by mobile technology.

The application interface displays geolocation information of the defined heritage data and the location of the device. The base map information is obtained from map servers previously implemented (Google Maps, Apple Maps, OpenStreetMap, Nokia Here or Bing Maps), which are supplemented with information from the territorial heritage of Salamanca previously selected for educational purposes. Additionally, the AR framework presents the resources included in the platform, based on location data and previously-defined points of interest. These contents correspond to the 3D models, audio, text and video of each heritage building (Figure 4). These digital implementations are a functional and thematic added value to be established as a basis for the teaching-learning process proposed by this mobile tool. The result of this step means the completion of the MPNS-AR software on territorial heritage in Salamanca, which will be evaluated in the next stage.

C. Design and Implementation of the Assessment Instrument

For the quantitative dimension the main instrument for data collection will be the same software created and implemented on tablets for users (students). Measurements shall be made by the following acquisitions made by the digital system:

- 1) Indirect measurements will be referred to application data in connection with the implemented graphic user interface, queries made, connectivity used, data transfer, consultation of multimedia resources and navigation done.

- 2) Direct measurements will be referred to an evaluation system applied to students in order to obtain data on the usability, perception and learning process received (effectiveness and significance).

For both dimensions, ad-hoc instruments will be built with the respective evaluations of specialists and relevant research sources in a real educational context: high school students with study plans and programs including the concepts addressed in the tool. The case study methodology is used to understand the context and meaning of the educational experience proposed with the software, using in-depth interviews with relevant stakeholders, formal documentation and use of content from other related sources: social networks and forums to be implemented to complement the proposed process.

D. Processing and Analysis of Data Obtained

After obtaining the basic information, the data will be processed through the software for the development of representative spatial models [31], [32]. In addition to this, the values of the instrument will be entered and coded for statistical analysis. The results will be interpreted and analysed in the context of research, establishing educational dimensions, characteristics of learning, usability patterns and relationships of information structure developed in an environment of uLearning-mLearning [3], [33], [34].

IV. EXPECTED RESULTS

One expected outcome is the creation of adaptable software under the modular structure and the dimensions of mobility, navigation and virtual interaction, considering educational and thematic references (local heritage education). Thus, the improvement of all system components would facilitate and optimize its digital construction, which would result in the benefit of 4 main areas:

- 1) In the development of optimizations according to the progress and requirements necessary to improve the application for an informal or formal educational context.
- 2) In the functionality and educational effectiveness of AR digital models generated within a framework of resources for education.
- 3) In the understanding of digital space (mapping-localization) with the assistance of a digital and portable system.
- 4) In the territorial and heritage information within the mobility and portability offered by tablets and smartphones as devices applied to education.

From the educational perspective, it would be possible to argue that the developed tool (MPNS-AR mobile) has a greater effectiveness in the field of education, compared to similar standard methodologies and tools: books, maps and direct teaching. The use of this tool will be developed within the context of uLearning-mLearning, establishing that it is a suitable method for the acquisition of spatial knowledge and heritage within a framework of portability of mobile devices such as tablets.

V. CONCLUSIONS

The use and generation of a MPNS-AR program about urban heritage and an important sense of local identity has been proposed here as a new way of presenting content in the contexts of uLearning-mLearning. Additionally, the need to establish the strengths, potential, weaknesses and limitations of mobile devices (tablets) for the implementation of formal educational processes is another important line to consider in the development of possible implementations. The evaluation and development of this technology package allow adequate access to specific content and greater personalization in the teaching-learning process. In addition, this research puts a strong emphasis on implementation aspects and technological development, supplemented by determining their educational implications, allowing continuous improvement in each of the elements that constitute the MPNS-AR system. Ubiquitous Learning and Mobile Learning (uLearning-mLearning) are the areas that have the greatest impact with the development of mobile technologies on the dissemination of information and access to personalized data. The personalization of contents and processes in areas such as cultural heritage allows an improvement in the learning process, contextualizing content and local cultural identity.

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