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Alive Cemeteries with Augmented Reality and Semantic Web Technologies

Tamás Matuszka, Attila Kiss

***Abstract*—**Due the proliferation of smartphones in everyday use, several different outdoor navigation systems have become available. Since these smartphones are able to connect to the Internet, the users can obtain location-based information during the navigation as well. The users could interactively get to know the specifics of a particular area (for instance, ancient cultural area, Statue Park, cemetery) with the help of thus obtained information. In this paper, we present an Augmented Reality system which uses Semantic Web technologies and is based on the interaction between the user and the smartphone. The system allows navigating through a specific area and provides information and details about the sight an interactive manner.

***Keywords*—**Augmented Reality, Semantic Web, Human Computer Interaction, Mobile Application.

I. Introduction

SMARTPHONES have become an accepted part of our everyday life nowadays. With their help, to carry out many regular activities will become much easier [1], [2]. These smartphones have a variety of built-in sensors (for example, accelerometer, magnetometer, GPS sensor, temperature sensor, orientation sensor). Due to these built-in sensors, the mobile phone has the ability among others to detect the changes in the user's position which allows that the device could be used for navigation purposes as well. Due to the wider usage of smartphones, many navigation applications have been published [3]-[5]. These solutions determine the actual positions of the users based on the device's GPS sensor. After this method, the mobile phone is able to navigate the users to the selected destination. The above-mentioned approach is really perfect in that case, when the user just wants to get to a certain location. However, if the user wants not only to navigate through a specific area (for instance, ancient historical region), but also wishes to know certain information concerning the chosen destination, these applications do not comply for the users' purposes. Nowadays, smartphones are capable of fast and reliable connectivity to the Internet. Due to this opportunity, arbitrary information can be obtained from the Web within seconds. In this way, the current navigation applications could be extended with new functionalities. These augmented navigation applications would gather various location-aware information and make them available. In addition, the thus obtained data could be displayed by the application. With the help of such a system, the users can learn about the specifics of a certain area in interactive manner.

The purpose of this paper is twofold: First, we outline the theoretical aspects of the used technologies and give a new, formal definition of Augmented Reality. Second, we present a system which uses Augmented Reality and Semantic Web as well; furthermore, it is based on the interaction between the user and the mobile device. We describe the details of our system through a case study as a proof of concept. Semantic Web technologies have been used for storing our knowledge base in a uniform format and linking it with public datasets. Augmented Reality was used to facilitating the navigation and to displaying the context-aware information. The implemented application runs such smartphones which has Android operation system. Our program helps the user to become familiar with the characteristics of a selected area through the interaction with the device.

A. Overview

The organization of the rest of this paper is as follows. After the introductory Section I, we briefly overview the existing related work in Section II. In Section III, we outline the preliminary definitions. The details of our system are described through a case study in Section IV. Finally, the conclusion and the future plans are described in Section V.

II. Related Work

In the past few years, some studies on smartphone based navigation have been published. In this section, we outline and give a short overview of the most relevant works.

In a previous paper [12] we have tried to combine the advantages of Augmented Reality and Semantic Web to provide indoor navigation. In this work, we describe an indoor navigation system which uses Augmented Reality for visualization of navigation. The storage of data which are necessary to the navigation was based on ontology. In addition, the possible paths are generated by rule-based inferences.

In another previous work [10] we present the conception of a system that is similar to the application which is the subject of our paper. Reference [10] shows the scheme of a general, Semantic Web-based Augmented Reality system. Due to this framework, the user would navigate through arbitrary areas and get context-aware information.

Newton et al. in [13] present a mobile Augmented Reality application which provides navigation and visualization of a

Tamás Matuszka is with the Department of Information Systems, Faculty of Informatics, EötvösLoránd University, Budapest, Hungary and Inter-University Centre for Telecommunications and Informatics, Debrecen, Hungary (e-mail: tomintt@inf.elte.hu).

Attila Kiss is with the Department of Information Systems, Faculty of Informatics, EötvösLoránd University, Budapest, Hungary (e-mail: kiss@inf.elte.hu).

Singaporean cemetery, namely Bukit Brown Cemetery. The authors used natural feature tracking for recognition of tombstones. In addition, they applied GPS-based terrain clustering techniques. Due to this method, the computation time and cost can be reduced. Their system was used to visualize the heritage value of cemetery. Furthermore, the system superimposes important information about the tombstones into the real-world view.

Aart et al. in [14] explore the characteristics of location-aware smartphones for browsing and searching cultural heritage information. Their application determines the location of the user based on GPS coordinates and creates user context from the combination of nearby locations, local historic events, etc. The authors combine two type of knowledge. The first one is general knowledge (for example, about geolocations and point of interests). The second one is specialized knowledge about cultural heritage. The paper depicts three concrete case studies as well.

III. Preliminaries

In this section, the concepts that are necessary for understanding are defined. We provide insight into the basic concepts of Semantic Web and Augmented Reality.

A. Semantic Web

A possible way to manage the data available on the Internet is to use the Semantic Web [6]. The Semantic Web aims for creating a "web of data": a large distributed knowledge base, which contains the information of the World Wide Web in a format which is directly interpretable by computers. The goal of this web of linked data is to allow better, more sensible methods for information search, and knowledge inference.

Ontology is recognized as one of the key technologies of the Semantic Web. Ontology is a structure $O := (C, \leq_C, P, \sigma)$, where C and P are two disjoint sets. The elementsof$C$ and P are called classes and properties, respectively. A partial order $\leq_C$ on C is called class hierarchy and a function $\sigma: P \to C \times C$ is a signature of a property [7].

The Semantic Web stores the knowledge base as RDF triples. Let I, B, and L (IRIs, Blank Nodes, Literals) be pairwise disjoint sets. An RDF triple is a $\left(v_1, v_2, v_3 \in (I \cup B) \times I \times (I \cup B \cup L)\right)$, where v_1 is the subject, v_2 is the predicate and v_3 is the object [8].This way our data can be seen as a directed graph, where a statement is an edge labeled with the predicate, pointing from the subject node to the object node. The query language called SPARQL [9] formulates the queries as graph patterns, thus the query results can be calculated by matching the pattern against the data graph. The SPARQL is able to retrieve and manipulate data stored in RDF format. It is similar to SQL query language.

B. Augmented Reality

Augmented Reality applications are more and more widespread nowadays. With its help the real physical environment can be extended by computer generated virtual elements creating the illusion that the two worlds coexist. Augmented Reality has two different types. The first one is the marker-based Augmented Reality and the second one is the position based Augmented Reality. The marker-based one uses a so-called marker. This marker allows the registration of the virtual object in the physical space. The position based Augmented Reality depends on the user's physical position which is determined by GPS coordinates [10].

According to Azuma's definition, an Augmented Reality system combines real and virtual reality; is interactive in real-time and is registered in 3D [11].In this paper we give another, formal definition for the same concept. A quintet $\langle M, VE, T, \varphi, \xi \rangle$ is called as Augmented Reality system, where M is the set of markers, VE is the set of virtual elements, T is the set of transformations, φ is the mapping function and ξ is the transformation function. Let IB, PB (image-based markers and position-based markers) be two disjoint sets. Then, M can be written as follows: $M = IB \cup PB$. Let I, V, S and K (images, videos, sounds, knowledge base) be pairwise disjoint sets. In this case, $VE = I \cup V \cup S \cup K$. The T set contains geometric transformations, namely translation (τ), rotation (ρ) and scale (σ). In addition, let L be the set of 3D vectors. Every $v \epsilon VE$ virtual element has an $l \in L$ vector. This l vector stores the position of v virtual element. The function $\varphi: M \to VE \times L$maps a virtual element and its relative initial position to a marker. The last part of the quintet is the transformation function ξ. The function $\xi: M \times VE \times L \times T \to VE \times L$ transforms a virtual element corresponding to the given marker with a given transformation in real-time. The current Augmented Reality systems can be modeled by the above definition.

C. Problem Description

In this paper, we present an $\langle M|_{PB}, VE|_{KB}, T, \varphi, \xi \rangle$ Augmented Reality system, where the set of markers is restricted to position-based markers (i.e. the markers are limited to position-based type) and the set of virtual elements is restricted to knowledge base (i.e. the virtual elements are solely location-aware information). This knowledge base is stored in RDF triples and the semantic relations between the knowledge base are stored in O ontology. The function φ assigns relevant information based on the latitude and longitude coordinates of the places represented by markers.

IV. The Details of System

The section overviews the details of our system: the data collection and transformation method, the navigation module and the interconnection of the application with the Semantic Web. The system is described through an implemented case study. The Hungarian Kerepesi Cemetery was chosen as venue of our case study.

Kerepesi cemetery is one of the oldest graveyards in Hungary which has been almost completely preserved as an entity. The National Pantheon is part of Kerepesi cemetery, where several Hungarian notables are buried in ornate tombs or mausoleums. The graveyard is located in a huge area that includes one of the largest statue parks in Europe. Nowadays one can participate in a guided walk during which the tombs of famous deceased can be visited. With the help of this application the tour could be more interactive. Our purpose was to provide navigation among the tombs which are scattered over an enormous area. In addition, the system shows useful information about the deceased.

A. Data Collection and Transformation

In order to be able to display relevant information, the needed data had to be collected about the deceased of the Kerepesi cemetery. The knowledge base has been built with processing of several Hungarian websites. After this phase, the preprocessed data was transformed to RDF format. We have chosen RDF format for storing because it provides a unified data model which enables easily interlinking of our knowledge base with publicly available semantic format datasets. The Interconnection with Semantic Web subsection describes the details of these datasets as well. The HTML websites contain various information about the defunct (for example, a short description of the deceased's life, his occupation, an image about the people). The HTML format does not meet our goals. Therefore, as a first step; a data transforming application development was needed. The conversion program was implemented in Java language. This module processes the HTML page source file to produce an RDF output format. Fig. 1 shows the information in RDF format that was transformed from HTML source file about a deceased.

```
<rdf:Description rdf:about=
    "http://inf.elte.hu/cemetery/Lajos_Kossuth">
    <rdf:type rdf:resource=
        "http://xmlns.com/foaf/0.1/Person" />
    <foaf:name>Kossuth Lajos</foaf:name>
    <cem:parcel>Kossuth mauzóleum</cem:parcel>
    <foaf:depiction
        rdf:resource=
        "http://www.agt.bme.hu/varga/foto/kerepesi/kossuth.jpg" />
    <foaf:homepage>
        hu.wikipedia.org/wiki/Kossuth_Lajos
    </foaf:homepage>
    <dbpedia-owl:abstract>
        In 1832 at Bratislava, ...
    </dbpedia-owl:abstract>
    <dbpedia-owl:birthDate>1802-09-19</dbpedia-owl:birthDate>
    <dbpedia-owl:deathDate>1894-01-01</dbpedia-owl:deathDate>
    <cem:occupation>politician</cem:occupation>
</rdf:Description>
```

Fig.1 RDF representation of a deceased

Ontologies (mentioned in Preliminaries section) can be used to describe the hierarchy of complex conceptual systems, and to carry out knowledge inference. The schema of our knowledge was stored in a very simple ontology which builds on the FOAF vocabulary and the DBpedia ontology. This method fits one of the principles of Semantic Web, which has the purpose of reusing existing ontologies. The objective of FOAF [15] is to link people and theirs information using the Web. The DBpedia [16] contains the knowledge of Wikipedia in a semantic form. The following class and properties are used as a basis of our ontology. The `foaf:Person` class represents people and it is equivalent with `dbpedia-owl:Person`. The `foaf:name` is a property which represents the name of a people. The property `foaf:homepage` symbolizes a homepage that is related to a people. The `foaf:depiction` property is a depiction of something as image. The `dbpedia-owl:abstract` property means a small description of a thing, the `dbpedia-owl:birthDate` and `dbpedia-owl:deathDate` properties serve as the birth date and death date of a `foaf:Person`, respectively. Finally, we defined the `cem:occupation` property, which represents the occupation of a `foaf:Person`.

The application extracts the needed data from the knowledge base with the usage of the concepts which are defined in the ontology and with the help of the before mentioned SPARQL query language. SPARQL allows for a query to consist of triple patterns, conjunction, disjunction and optional patterns. We used the AndroJena API [17] to handling semantically represented data. AndroJena is a porting of Jena [18] semantic web framework to the Android platform. Jena is a free and open source Java framework for building Semantic Web and applications. Fig 2 depicts an example SPARQL query. This query returns the necessary information belonging to a given person.

```
PREFIX rdf:
    <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbpo:<http://dbpedia.org/ontology/>
PREFIX foaf:<http://xmlns.com/foaf/0.1/>
PREFIX cem:<http://inf.elte.hu/cemetery/>

SELECT ?name ?birthDate ?deathDate ?abstract ?occ
       ?homepage ?pic
WHERE {
    ?person foaf:name ?name .
    ?person foaf:homepage ?homepage .
    ?person foaf:depiction ?pic .
    ?person dbpo:birthDate ?birthDate .
    ?person dbpo:deathDate ?deathDate .
    ?person dbpo:abstract ?abstract .
    ?person cem:occupation ?occ .
    FILTER (str(?name)="Kossuth Lajos")
}
```

Fig. 2 SPARQL query which return information about a person

B. Navigation

Two approaches were used to provide the visualization of navigation: the first one is a simple map view. The second one offers Augmented Reality view. The details of Augmented Reality-based navigation are explained in this subsection.

As a first step in order to allow the navigation, the creation of the map of Kerepesi cemetery was needed. The latitude and longitude coordinates of the graves and the junctions (those are necessary for the navigation) was acquired after a prior measure phase. The coordinates of graves, junctions as well as the paths among the junctions were stored in separate text files. After this data-acquire phase, the application is able to build from the stored data the connected, undirected graph which represents the given map. In possession of resulted graph, the well-known shortest path algorithms can be used easily. In our case, the Dijkstra algorithm [19] was used to calculate the shortest path to the destination.

Once the preprocessing phase the required data was made

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available for the application, the actual navigation may starts. One option offered by the program makes available a map view. This was achieved by Android Google Maps API [20]. The user has the option to select a tomb to which she/he wants to navigate. Thereafter, the system determines the closest junction to the current position based on the GPS coordinates of mobile phone. Thenceforth, it calculates the shortest path to the selected destination by way of Dijsktra algorithm. Finally, the application displays this path on a map and follows the user's movements and shows it on the same map as well. Fig. 3 shows an example of this method.

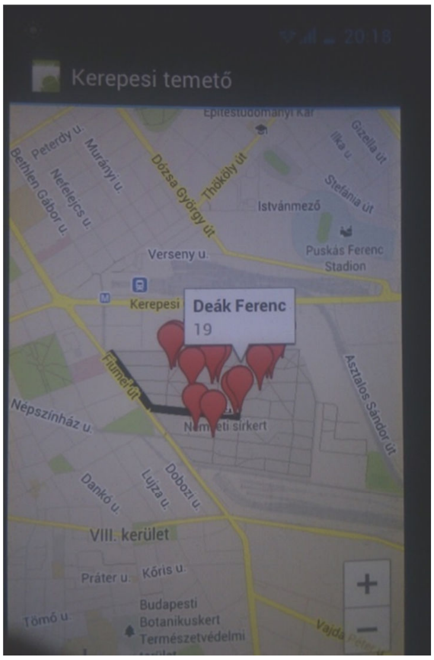

Fig. 3 Navigation with simple map view

The other visualization solution is based on the Augmented Reality. Currently, several Augmented Reality engine already available, but we decided to implement an own module. The reason was that the existing Augmented Reality engines are typically complex, resource-intensive as well as difficult to use. Accordingly, we have implemented an own Augmented Reality module, which based on the mathematical model described in [21]. This module is easy to use and with the help of it is simple to implement location-based Augmented Reality applications. Once the user navigated the nearest junction of the selected tomb by using the map view, the Augmented Reality-based navigation allows him to get to the final destination. The user could see the distance between the current position and the selected tomb via the camera of smartphone. The right direction towards its final destination is displayed as well. Fig. 4 illustrates an example of the operation of this module.

Fig. 4 Augmented Reality-based navigation

Due to the built-in sensors, the device knows when the selected grave is in the field of view of the phone based on the GPS coordinate and the current position. In this case, a virtual element which represents the tomb will appear on the camera screen. At this point in the navigation arises the opportunity to display and browse the additional information that is stored in the knowledge base. The system gets the relevant information from the semantically represented data by using SPARQL queries at this time, and then builds up the graphical user interface that allows viewing of data. The most important information can be viewed in a real-world view. Since the tomb representing virtual element will disappear when the grave itself out of the camera's field of view, the user should keep the grave constantly on the field of view of the smartphone's camera, which leads to inconveniences. To counteract this, we have introduced that the information about famous deceased is displayed in a new window when the user click on the virtual element.

C. Interconnection with Semantic Web

In the previous subsection we have seen that the Augmented Reality technology allows the user to view information stored in the knowledge base when the chosen grave is reached. However, due to the semantic format storage, we can acquire much more knowledge about the selected famous deceased. Nowadays, there are numerous databases which contain theoretical and experimental results of various scientific experiments in the field of computer science, biology, chemistry, etc. There is quite a complex collection of these kinds of data maintained by the Linked Data Community [22]. Since the knowledge base is stored in RDF format, as a result, it can be interlinked with publicly available semantic datasets; which includes the DBpedia (that was mentioned in the Section IV) as well. The query shown in Fig. 5 finds the location of the birth and the death of a person from the DBpedia dataset. This information is not part of our knowledge base. This type of combination of different datasets is another indication of the potential benefits of Semantic Web technologies during the data integration.

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```
PREFIX rdf:
    <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbpo:<http://dbpedia.org/ontology/>
PREFIX foaf:<http://xmlns.com/foaf/0.1/>

SELECT ?name ?birthPlace ?deathPlace
WHERE {
    ?person foaf:name ?name .
    ?person dbpo:birthPlace ?birthPlace .
    ?person dbpo:deathPlace ?deathPlace .
    FILTER (str(?name)="Lajos Kossuth")
}
```

Fig. 5 Connect our knowledge base with DBpedia

V. Conclusion

Due to the wider usage of smartphones, various navigation systems have been published nowadays. In this paper, we presented an Android-based mobile navigation system, which uses Augmented Reality and Semantic Web and based on the interaction between the user and the mobile phone. First, we formalized the definition of Augmented Reality system. Thereafter, the details of the system were given through a case study as a proof of concept. Semantic Web technologies have been used for data storing and additional information retrieving. In addition, the semantically represented data was displayed by Augmented Reality and it was used to facilitating the navigation method as well.

In the future, we would like to use more publicly available datasets. We are working in other project on a mobile semantic browser which enables to browse the Linked Open Data. We would like to build up that browser into our navigation system as well. As a result, the user could find out more information about what she/he is interested.

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