STAG: Smart Tools & Apps for Graphics (2014)
Andrea Giachetti (Editor)

AR Turn-by-turn navigation in small urban areas and information browsing

Gianmarco Cherchi, Fabio Sorrentino, Riccardo Scateni

Department of Mathematics and Computer Science, University of Cagliari - Italy

Abstract

Navigation systems allow to discover cities and their urban areas easily and quickly, finding the shortest path to reach them and giving directions to users saving their time and energy. At present time, these systems are based over streets maps offered by the major mapping services like Tele Atlas, Navteq or OpenStreetMap.

In recent years, thanks to the Google StreetView service it has been possible to discover main cities locations both indoor and outdoor. What is missing in this frame is the possibility to map small urban areas of small and medium sized cities, due to their lack of relevance for the big players. In this cities there could be very interesting areas for tourists. Example locations could be botanical gardens, archeological sites, protected natural areas among others.

In this work we tried to set up a navigation system for limited extensions inside urban areas which permits to wander around and gives access to related information using augmented reality techniques. Due to the possible poor wireless coverage in these locations we designed an application that stores all required data on the user's device, splitting the information in packages according to the chosen language.

A key issue was to achieve good results combining all these features in a single device with a small display, overwhelming the constraints due to the mobile environment.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1. Introduction

Navigation systems allow to discover cities and their urban areas easily and quickly, finding the shortest path to reach them and giving directions to users saving their time and energy. These systems are usually based over streets maps offered by the major mapping services like Tele Atlas [Atl], Navteq [Nav] or OpenStreetMap [Ope]. Google StreetView has added the possibility to enter inside the map and to discover lots of cities locations both indoor and outdoor. Private areas, and all the areas not accessible to the Google crew are still not available, and this is true for most of the urban areas of this type in small and medium sized cities, due to their minor relevance. But in these cities there could be very interesting areas of this kind for tourists like botanical gardens, pedestrian only accessible archaeological or historical sites, natural areas and such.

Often, in this sites, visitors are supplied with flyers and guide books that possibly include a map with the major points of interest (POIs). At the same time, several city e-guides are available to tourists for their mobile devices, and sometimes these guides are just PDF files often combined in native apps developed for mobile systems like iOS, Android and WP. The aim of our work was to develop a system for the guided exploration of small, not Streetview-accessible, urban areas giving access to the most relevant information using augmented reality techniques. Since we cannot always rely on wireless coverage we designed an application that stores all the required data on the user's device, splitting the information in language-based packages. We than packed all the features in a single app for mobile systems taking in account the size of the display and the features of the device available on the mobile platform.

2. Related work

We have analyzed several works looking for applications having in common the same technology (augmented real-

DOI: 10.2312/stag.20141237

ity), the same device targets (smartphones and tablets) and the same focus (tourism services). Both commercial applications and scientific prototypes are usually general purpose AR broswers used to show different points of interest, giving their geo-located position and related information. In these works, the augmentation of the reality regards the overlaying of digital contents, based on the POI's GPS location, like label or placeholder.

In [MGS*12] Mulloni and colleagues say that the road toward such kind of applications is not easy due to a lack of precision of navigation systems. Nowadays, this drawback is less penalizing thanks to new mobile devices sensors that are faster and more accurate. This works demonstrates how users, that have access to the information provided on a 2D map or via AR, prefer in most cases the use of the 2D map because it gives greater precision and reliability compared to the use of the augmented reality one. In order to have better results, and better usability of the AR applications while increasing the accuracy, additional techniques are required. These techniques are the same used in indoor navigation systems. These systems consist in specialized navigation applications for indoor environments that use both orientations sensors and phone camera to guide the user inside a building without the GPS usage. They were developed in order to create guides for museums or large buildings. An example of such a kind of indoor navigation system can be found in [SDC*10].

Talking about museum exploration another interesting work using augmented reality is [CCH14]. Here the prototype uses a camera that recognize hands movements above a marker and a corresponding action is performed. Using this approach it is possible to observe and manipulate 3D digital replicas of artifacts in real-time using hand-gestures instead of the traditional keyboard and mouse setting. It is a type of AR based exclusively on markers placed on various points of interest in the museum. It provides information on the POI but the user is not guided inside the museum.

In our work augmented reality is used to enrich the navigation task and not just for giving more information at the point of interest location.

3. Application design

As a proof of concept we created a first prototype, that we called AR-Garden, considering a botanical garden as case study. We wanted to support visiting scenarios where tourists decide to visit the garden autonomously without the aim of a tour guide. After an initial configuration, the AR-Garden application allows users to navigate in the botanical garden sectors autonomously, providing garden information like sectors, plants species, points of interest and giving directions to reach them. Its main goal is to simplify the user's visit through a system of geolocated garden areas and points of interest keeping track of user's position. Following well known techniques used in navigation systems we created a very simple interface easy to use, allowing to choose a destination point and showing how to reach it in a fashion similar to the one of car navigation systems. Our main problem was to achieve results similar to those of car navigation offers but with the constraints that streets are smaller, points of interest are really close each other and, in some cases, the GPS error could be very high.

We then combined several principles taken both from indoor and outdoor navigation, trying to mix them offering a turn-by-turn reliable system for visitors devices.

3.1. Small urban area definition

As said before, in this work we focused on small urban areas, meaning those city areas as botanical gardens, parks or whatever part that usually have these common characteristics:

- Dedicated to pedestrians and/or cyclists;
- Can be mapped on a 2D map;
- Smaller (even much smaller) than 20 square kilometres;
- Interesting spot for tourists;
- Located outdoors.

3.2. User Interface

From the initial screen is possible to access all the application features. Choosing among them through a menu bar the user is redirected to the relative feature view.

Figure 1: *Main screen for navigation.*

The navigation feature, the most important, allows the navigation turn-by-turn. In the lower part of the screen a 2D map is shown; on the map the user's location is over-layered and there are the destination point and the path to follow to reach it. In the upper part of the screen, the phone's camera preview is used, combined with augmented reality signals giving direction to reach the destination point. A 3D arrow points to the current destination point (see Fig. 1). Using both views users can easily reach their selected points of interest, saving time and energy. The user is also able to change these two views in different ways depending on his/her preferences (see Fig. 2).

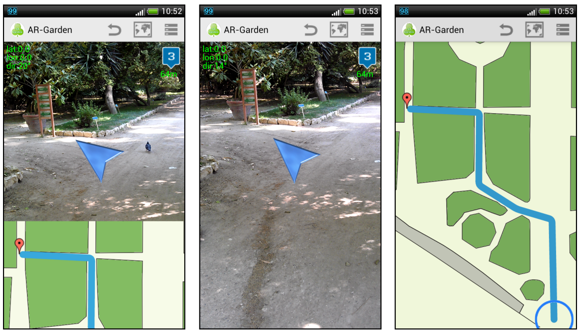

Figure 2: *The three layouts for navigation: combined (left), only AR (center), and only map (right).*

As we said before augmented reality techniques play an important role in the AR-Garden prototype. The surrounding environment, captured through the device camera, is augmented with additional information regarding the nearby and geo-located points of interest layered over the stream of images. This means that the information about the position and the direction to follow are shown when the user is in a particular location. Using system calls it is possible to retrieve all sensors values such the current location (using latitude and longitude), the azimuth, the direction to follow (pointed using an arrow icon), the destination sector and the estimated distance to cover to reaching it. Other tabs allow to open the sectors view and the related information (in this case the plants and trees). The sectors area tab shows a list of all garden zones where a list of all plants is shown (see Fig. 3).

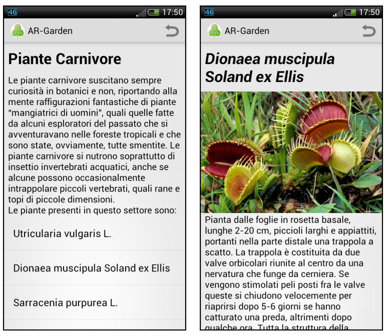

Figure 3: *The information on a single sector (left) and on a single plant (right).*

For each plant there are more information available like the scientific name, a picture and detailed data such as the family, the habitat, flowering period and more.

3.3. Map

The map is managed as a 2D image with an overall resolution of 2000×4205 pixels, allowing a good visualization on devices with different screens sizes. In the system memory we store only a part of the map (the currently visible one) that is a subimage obtained cropping the original one. This technique leads to an efficient use of system resources and consequently to a more fluid application usage. We developed our application prototype on Android 2.3.3. This Android version is installed on phones and tablets with a single core where loading the entire map in the memory is too heavy. The trick used to improve the map loading allows the application to be used also on middle range devices. On the map we also implemented the classic manipulation events such as *Drag* and *Pinch to Zoom* to improve the navigation functionality.

3.4. Augmented reality

With the word augmented we mean a process of enrichment the reality perceived through the five senses, adding digital information using a computer or a mobile device. In tourism related application, this technology is often used to show information related to a city or a monument that one is just visiting. There are basically two types of augmented reality:

- The first one is the geo-localized AR, usually used in mobile devices equipped with a positioning system and with a set of motion sensors; through the screen device the surrounding environment is enriched with more information on several layers based on geo-localized POI's;
- The second one is based on ARTags, used both on mobile devices and desktop computers through the detection and recognition of specific markers (usually drawn with black and white geometric shapes); recognizing these markers it is possible to show digital media like photos, videos, 3D models combined with audio file adding interactivity to the experience.

In our case study we used geo-localized AR. In order to do it we use the device built-in sensors like the GPS or the compass. The GPS sensor provides information on the user's location using longitude and latitude and the compass sensor provides the azimuth measure.

3.5. Shortest path

To find the "best" path between two points we have to store first a set of nodes and a set of existing paths, storing these information in a graph. In this structure, each node represents an area of the map or a cross between two paths, while the arcs between the nodes represent the possible connection between the various sectors. The "shortest path" Dijkstra's algorithm implementation made possible to search for the best routes between sectors/nodes.

3.6. Navigation

Using the obtained information by the device sensors, and using appropriate geometric operations, the user's position can be plotted over the map. In our implementation we use the map as a Cartesian plane, transforming the previous (A point) and the current (B point) GPS position in XY coordinates on the plane. After every position's update the distance between A and B and the angle between the straight line passing through the two points and the X-axis are computed. To find the new position we calculate Δ_x and Δ_y and we add or subtract them appropriately to the current position. In particular $\Delta_x = \text{dist} \times \cos\alpha$ and $\Delta_y = \text{dist} \times \sin\alpha$, where dist is the distance between the two geographical positions appropriately transformed into pixels, and α is the angle between the straight line passing through the two points and the X-axis calculated using the following formula (where Lat=latitude, Lon=longitude):

$$dy = \text{Lat}(B) - \text{Lat}(A)$$
$$dx = \left(\cos\left(\frac{\pi}{180} \times \text{Lat}(A)\right) \times \text{Lon}(B) - \text{Lon}(A)\right)$$
$$\alpha = \arctan(dy, dx) \times \frac{180}{\pi}$$

The following step consists in recomputing the direction of the arrow (that indicates the way the user should follow to reach his/her destination) based on the last position update. This is done by considering the current position, the target position and the user's orientation based on the destination. We calculate the angular coefficient m of the straight line passing through the points A and B where A represents the current position and B is the point to be reached.

$$\Delta_x = x_A - x_B$$
$$\Delta_y = y_A - y_B$$
$$m = \frac{\Delta_x}{\Delta_y}$$

Δ_x or Δ_y equal to 0 mean that the user is moving along one of the Cartesian axes otherwise we find the angle of rotation of the arrow calculating $\arctan(m)$.

4. Conclusion and future work

Brochures paper and bulky signals often used in small areas such as a botanical garden can be replaced using digital tools such as AR-Garden. The user interface, for this reason, was created simple and intuitive, without too complex features or annoying graphics elements that can distract users. Overall we are satisfied with the achieved results, and we envision that using other sensors and techiques used in indoor navigation system our application can be improved.

The AR-Garden application has been tested in two steps: the first one emulating the user position and the second one directly on-site. To emulate the GPS signals we used an Android emulator using a gpx file. Through a connection between the terminal system and the emulator it is possible to simulate the GPS coordinates evaluating the application behavior in a controlled environment, avoiding GPS signal precision issues. The provided directions, using augmented reality (based on user's position and destination point), are correctly displayed as expected. Thanks to these results we can affirm that the used navigation algorithm is enough accurate for our purposes.

Once we decided to try the application on site we have obtained different and not so good results. The well known GPS signal error is really significant and caused bad results during our testing. The main problem was due to signal strength, since the signal acquisition is difficult in covered, or partially covered, areas (i.e., during a cloudly day in a park with trees). This leads to high errors in the device positioning during the environment discovering. In our case of study, the Botanical Garden of Cagliari, we have encountered this problem because it is almost totally covered by trees forming a barrier between satellites and user's device. This leaded to a low GPS signal or a distorted pair of coordinates, and we have estimated that this error was even 20 meters in the worst cases. This implies that the navigation based on GPS coordinates is not enough to offer a good turn-by-turn navigation in these kind of areas. We are working on a new application version that uses inertial indoor navigation systems to achieve better and reliable results.

Our future plans include the development of a complete framework able to let developers create a turn-by-turn navigation system just changing the application contents.

References

[Atl] ATLAS T.: `mapinsight.teleatlas.com`. 1

[CCH14] CHEN C.-Y., CHANG B. R., HUANG P.-S.: Multimedia augmented reality information system for museum guidance. *Personal and ubiquitous computing 18*, 2 (2014), 315–322. 2

[MGS*12] MULLONI A., GRUBERT J., SEICHTER H., LANGLOTZ T., GRASSET R., REITMAYR G., SCHMALSTIEG D.: Experiences with the impact of tracking technology in mobile augmented reality evaluations. In *MobileHCI 2012 Workshop MobiVis* (2012). 2

[Nav] NAVTEQ: `www.navteq.com`. 1

[Ope] OPENSTREETMAP: `www.openstreetmap.org`. 1

[SDC*10] SERRA A., DESSÌ T., CARBONI D., POPESCU V., ATZORI L.: Inertial navigation systems for user-centric indoor applications. *Networked and Electronic Media Summit, Barcelona* (2010). 2