Augmented Reality in Mobile Devices Applied to Public Transportation

Manuel F. Soto[1], Martín L. Larrea[2], and Silvia M. Castro[2]

[1] Instituto de Investigaciones en Ingeniería Eléctrica (IIIE) "Alfredo Desages"
Univesidad Nacional del Sur,
Consejo Nacional de Investigaciones Científicas y Técnicas.

[2] Laboratorio de Investigación y Desarrollo en Visualización y Computación Gráfica (VyGLab),
Departamento de Ciencias e Ingeniería de la computación,
Universidad Nacional del Sur.
{mfs,mll,smc}@cs.uns.edu.ar

Abstract. Augmented Reality (AR) is one of the most revolutionary technologies at these times. It improves the real world by additional computer generated information. The AR paradigm opens new ways for development and innovation of different applications, where the user perceives both, virtual and real objects at the same time. With the rise of SmartPhones and the development of its characteristics, the AR on mobile devices emerging as an attractive option in this context. In this paper we present the design, implementation and testing of an application of AR on Android platform for mobile devices. This allows a person traveling through the city gets information of routes, timeouts, etc; about a particular bus line. All this information is provided on the mobile device and associated to the real world, facilitating their interpretation.

Keywords: Augmented Reality, OpenGL ES, Android, Public Transport, OpenStreetMap

1 Introduction

Nowadays, technological advances in the area of mobile devices are constant. The increase in processing power, the storage, quality of cameras and screens have given rise to the development of applications of Augmented Reality (AR) on these devices. This situation is further benefit by the low cost of mobile devices, and easy Internet access from them. In this context, we designed and developed an application to assist the user that is in a certain place in the city and want to take a bus, through its mobile device the user will know if the bus route is close to its location.

In this paper we present an application of AR based in *Android* oriented to SmartPhones that allow the user to enrich the physical information of the environment with virtual information such as routes of bus, lines that pass within 300 meters of the place in which the user is located, the arrival times, etc.

More specifically, the system can display the bus routes over the street that the user has in his front superimposed on the video stream on his mobile device. The user can also get information about a queried bus line, an estimate of arrival times for the next bus and a view of selected bus routes. The user's position is obtained from the *GPS*[3], orientation from the accelerometers and gyroscopes and georeferences data are downloaded from *OpenStreetMap* (OSM) servers.

The structure of this paper is as follows: The following section will provide an overview of the history of AR, AR on mobile devices and existing information systems relative to public transport. The third section will present the developed system architecture. Details of implementation will be provided on the fourth section. The fifth section will show the case study and finally outline the conclusions and future work are presented.

2 Background

We will introduce basic concept in references to AR, AR on mobile device and systems for visualization of maps and routes over them.

2.1 Augmented Reality and Mobile Devices

The term Augmented Reality (AR) is used to define a direct or indirect view of a real physical environment which elements are merged with virtual elements to create a real-time mixed reality. Guided by Figure 1 we can see where is placed the AR within the world of mixed reality [9].

In 1997 *Ronald Azuma* presented the first study of AR [4]. This publication established the physical characteristics of the AR, ergo the combination of real world and the virtual, real-time interactions and sensing in 3D.

Fig. 1. Graphic illustration of the concept of Mixed Reality.

AR applications can be classified into two types: *indoor* and *outdoor*. While the former are used in closed environments and their goal is to work without

[3] Global Positioning System

user restrictions ([3],[6]), the latter are applications that have no environment restrictions.

Outdoor applications are based on two types of technologies: portable and immersive ([3],[6]). The first type consists in making a computer graphics overlapping on camera view of the portable device. In the second type must have generally, a *Head-Mounted Display* HMD that allows overlaying the images directly into the user's view, thereby achieving high levels of immersion.

In 1968 *Ivan Sutherland* created the first mobile AR system [14], which consisted of two trackers for correct positioning of images, each one with 6 degrees of freedom, one was ultrasonic while the other was a mechanic.

Later, in 1992, *Tom Caudell* and *David Mizell* first used the term *AR* [5] to refer to the computer image overlay on reality. At that time, the HMD, was the only means envisaged for mobile AR applications.

In later years there were two important developments: these were the Tobias Höllerer ([7],[2]) and Mathias Möhring ([10]). The first allowed to the user explore the story of a tourist spot through mobile device pointing it to different parts of the same spot, while the second developed a 3D tracking system for mobile devices and the screen displays information associated with AR mode.

Recently, research in this area (AR) has focused on mobile devices. In early 2000, developed projects such as *Bat-Portal* [11], it was based on *Personal Digital Assistant* (PDA) and technology *Wireless*. The PDA was used as a client to capture and transmit video to a dedicated server which performed the image processing and proceeded to render and compose 3D objects. While initially the prototypes were based on a distributed strategy to delegate the graphics processing, the fast advancement in mobile phones allowed the development of applications that recognize markers in the environment. Subsequently, with the integration of new sensors on devices and growth in computing processing power, the field of AR applications for mobile devices grew exponentially [10] [12] [15].

In 2007, Klein and Murray [8] presented a robust system capable of tracking in real time, using a monocular camera in a small environment. In 2008 *Wikitude* AR browser [1] was launched, it combines GPS and compass data entries in the *Wikipedia*. Finally, in 2009 *White* introduced *SiteLens* [16], an system and set of techniques for supporting site visits by visualizing relevant virtual data directly in the context of the physical site.

2.2 Maps Visualization and Routes

There are several alternatives when it comes to display maps on mobile devices. One of them is the version of *GoogleMaps* oriented phones, the software creates the same experience for the user as a query from *GoogleMaps* web page. Another alternative is *Mobile Gmaps* (MGMaps), it is developed with technology *J2ME*, for maps obtaining the system consults sources such as *Yahoo! Maps*, *Windows Live Local* [4], *Ask.com* and *Open Street Map* (OSM), the features are similar to those of *GoogleMaps*.

[4] MSN Virtual Earth

There are also applications that use the voice as an alternative to navigation; an application of this style is *Aura Navigation*, which allows to the user to view route maps and move respects these using the user's voice as a guide.

Finally, some applications that use AR for display are *Wikitude Drive* and *GPS Cyber Navi*. They show a route previously configured by the user, allowing it to reach its destination in a different way.

From the literature it can be seen that there is no previous works using AR oriented to bus routes displaying on mobile devices.

3 BusWay-AR

When users are in a particular bus stop, usually they can access to the bus line that arrive to the stop; generally, there is no information about arrival times, bus routes, their location, etc. Additionally, it is useful to know what are the bus lines that circulate in a certain radius close to them and where they circulate. This motivated us to develop an application that would provide information associated with buses lines that are in a user environment.

The application developed through AR interface provides the user who is located in a certain geographical position information about: accessed bus line, the route of this and arrival times. The system can track the user and display a 2D augmentation of bus routes showing the path, if the path is round trip or return route, in addition to other information. All of this information is added to the field of view on the mobile device video stream. The information of the bus lines is obtained from the *OSM* servers. The application was developed on a *SmartPhone* equipped with camera, 3G connectivity, Wirelees, GPS, accelerometers and gyroscopes.

The system can determine the position and orientation of the user, to obtain information concerning to the bus line, routes, arrival and departure, calculate the estimated arrival times to the user's position and finally, display all this information in a graphical interface, which overlaps layers of information to the video stream of the mobile device.

3.1 System Architecture

The proposed system consists of five sub-systems: the processing of the route, the position for obtaining and calculating arrival times, the rendering, the user interface and the AR.(Figure 2)

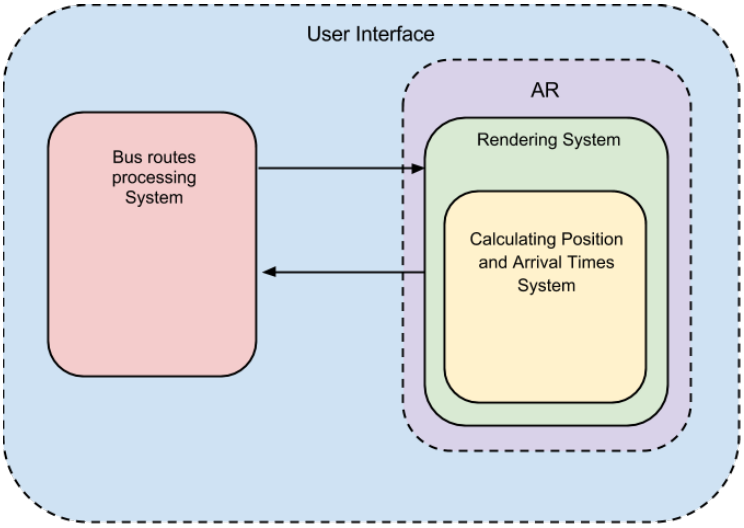

Fig. 2. System Architecture.

The *Route Processing Subsystem* is on charge of processing the path of the line selected by the user, which is communicated to the system via data provided by the graphical interface. Once the line has been obtained on request, is queried to *OSM* servers, the obtained information is stored in a suitable structure and is communicated to the *Rendering Subsystem*.

Obtaining Subsystem Calculating Position and Arrival Times is responsible for obtaining the user geographical position and the start time of the bus line consulted. From both, the subsystem proceed to calculate the arrival time and retrospective communicates to the *Rendering Subsystem*.

The *Rendering Subsystem*, which is responsible for generating the image displayed to the user, receives as input the path of the selected bus line and the user geographical position; it performs calculations for correctly positioning points of the route on the screen and also the bus position, it will be drawn only if the bus is within the range of view of the user. It is also responsible for providing information to the user, about arrival times, user geographical position, GPS status, etcetera.

The *AR Subsystem* is on charge of linking information from the *Rendering Subsystem* and the *Obtaining Subsystem Calculating Position and Arrival Times*, to be used for the system.

Finally the *User Interface* is the way by which the system communicates with the user, the latter being able to denote their needs and see the answers.

4 System Implementation

The system implementation was developed on *Android* and is intended to operate with bus routes of the city of *Bahía Blanca*.

The *Processing Subsystem* starts to work after the user selecting a bus line, the bus line is communicated to the subsystem that is responsible for making a query to the OSM page[5] where the bus line route is stored. The results are stored in an *XML* file.

For the development of *Positioning Subsystem*, we proceeded to obtain the user geographical position. *Android* provides several options, one of them is to use the built-in *GPS* sensor on the mobile device, to use it *Android* provides the *LocationProviders* data type, which can give us the position in two different ways: *GPS-Provider* and *Network-Provider*. We opted for the use of *GPS-Provider* as its accuracy was better.

Finally, the *Subsystem of Calculating Arrival Times* is responsible for telling the user how long it would take the next bus to arrive to the bus stop or where the bus is located, that was done by algorithms that estimate arrival times, based on data provided by the municipality of *Bahia Blanca* [6].

The *Rendering Subsystem* is responsible for drawing the scene viewed by the user. To this propose it should be taken into account the device orientation and the user interaction with the information displayed on the screen. Due to the complexity involved in the tasks outlined in the preceding paragraphs, we will see how their implementation were carried out.

For obtaining the image from the camera, *Android* provides access to the camera frames by modifying the main configuration file. Once we get the camera preview, we had to get the device orientation. *Android* provides us with a set of sensors, in particular, the sensor *TYPE_ROTATION_VECTOR* gives information about accelerometer and magnetic field. In this way we obtain the orientation of the device relative to the axis of the earth (aligned to the north), which is essential given that our system will use real positions (latitudes and longitudes).

To perform rendering of objects in the AR system, we used *OpenGL*, this gives us an API[7] with primitive graphics for drawing simple shapes. In our case, *Android* provides a special version of *OpenGL* for mobile devices, *OpenGL ES*. The version used was 1.0. Since we wanted to draw on the camera frames, we had to create a scene in our *OpenGL* space. The scene consists in objects, routes, which are in the *OpenGL* world space and an associated camera which will be rotated and moved in order to observe different objects from different points of view.

Since our main goal is to draw the routes of the bus line on the camera frame and the route consist on a set of latitudes and longitudes, we must convert those latitudes and longitudes from the world coordinate system to *OpenGL*

[5] http://wiki.openstreetmap.org/wiki/Bahía_Blanca/transporte_publico
[6] http://www.bahiablanca.gov.ar/conduce/transporte1.php
[7] Application Programming Interface

coordinate system. In order to perform the conversion, we had to keep in mind that we are referring to a geodetic coordinate system (latitudes and longitudes) and a geocentric coordinate system (*OpenGL*), in this way we have to made the respective transformations based on data provided by the next equations:

$$1/f = \text{flattenig factor} \tag{1}$$
$$e^2 = (a^2 - b^2)/a^2 = 2f - f^2 \tag{2}$$
$$\upsilon = \frac{a}{\sqrt{1 - e^2 \sin^2 \varphi}} \tag{3}$$
$$X = (\upsilon + h) \cos\varphi \cos\lambda \tag{4}$$
$$Y = \upsilon + h \cos\varphi \sin\lambda \tag{5}$$
$$Z = [(1 - e^2)\upsilon + h] \sin\varphi \tag{6}$$

where h is the *GPS* height and the variables a and b are the length of semi-major axis and the semi-minor axis of Earth respectively. λ is the longitude and φ is the latitude.

From above equations (based in [13] and [17]) were transformed latitude and longitude to X, Y and Z coordinates to draw the scene in *OpenGL*.

Needless to say, we used a *float* value in the internal representation for position, latitudes and longitudes are expressed in *double*; the systems perform the transformation with a lost of accuracy, therefore it is possible that in some cases there is shifting between the actual data and those generated by *OpenGL*.

5 System Testing

For testing we proceeded to the selection of the bus line 503 of the city *Bahía Blanca*. Since we want to analyse the system response under different circumstances, a prototype interface was developed, the interface can select the bus line manually, also the user must specify if he/she is in a default position or if the position can be get by the *GPS* (Figure 3).

Once the user have selected the option to show bus route, the route was displayed, both round trip (green) and return route (red), the GPS status (ON/OFF), latitude and longitude of the user geographical position, address (street/number), the arrival times from the round trip bus and the return route bus, this can be seen in Figure 4.

Data were obtained and the system was tested with both the *GPS* turned on and off, this can be seen in Figure 4.

It can be seen on the left of Figure 4 a map with way points recorded within a certain radius, you see green dots (round-trip), red dots (return journey) and a yellow dot(user's position). The right side of Figure 4 shows the view that the user has on the mobile device, the shifting between the bus route and the street is due to the *GPS* error and the rounding data error (move from *double* to *float*).

Selection of users geographical position.

Drop-down list with possible bus lines to consult.

Selected bus line.

Fig. 3. Prototype Interface.

Result of routes, bus line 503.

User looking the left with GPS ON.

Fig. 4. Caso de test del recorrido línea 503.

6 Conclusions and Future Work

Despite the technological advances in recent years, there are still difficulties, for example, in obtaining the position and orientation in large areas, the size of displays and graphics processing capabilities. However, the AR is a useful and versatile alternative to organize and contextualize the information. We have presented the design and implementation of a 2D mobile AR application where the visualization of the route of a particular bus line is superimposed on the mobile device video stream with addition of estimated arrival times, get the user's position and display all this information contextualized in the user interface.

In the testing performed we highlight the problems generated by both *GPS* accuracy and the loss of precision due to transform latitude and longitude coordinates to *OpenGL* coordinates. These problems lead to a shift in the routes visualization. Even though the objective of obtaining different kind of information about a particular bus line, these problems must be solved yet. About the positioning, it should work better with a higher precision *GPS* or with *DGPS*[8]. With respect to coordinate transformation, we should find an alternative representation in fixed point for latitude and longitude and with a defined range, perform a more accurate conversion into the *OpenGL* coordinate system.

In addition to seeking to solve the above problems, the future work is to be conducted online recognition of *OCR*, use version 2.0 of *OpenGL ES* and make the system has a 100% coverage information about bus lines. This paper is a starting point for the development of outdoor applications as we believe that this is a field of application in which mobile devices can be a very versatile alternative they record graphics on outdoor environments freely.

7 Acknowledgment

This work was partially funded by the project 24/N028 of Secretaría General de Ciencia y Tecnología, Universidad Nacional del Sur, PICT 2010 2657, FSTICS 001 "TEAC" and PAE 37079.

References

1. http://www.wikitude.com
2. Third International Symposium on Wearable Computers (ISWC 1999), San Francisco, California, USA, 18-19 October 1999, Proceedings. IEEE Computer Society (1999)
3. Avery, B., Smith, R.T., Piekarski, W., Thomas, B.H.: Designing outdoor mixed reality hardware systems. In: The Engineering of Mixed Reality Systems, pp. 211–231 (2010)
4. Azuma, R.T.: A survey of augmented reality. Presence: Teleoperators and Virtual Environments 6(4), 355–385 (Aug 1997)
5. Caudell, T.P., Mizell, D.W.: Augmented reality: an application of heads-up display technology to manual manufacturing processes. Proceedings of the TwentyFifth Hawaii International Conference on System Sciences 2, 659–669 (1992), `http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=183317`
6. Gotow, J.B., Zienkiewicz, K., White, J., Schmidt, D.C.: Addressing challenges with augmented reality applications on smartphones. In: MOBILWARE. pp. 129–143 (2010)
7. Höllerer, T., Pavlik, J.V., Feiner, S.: Situated documentaries: Embedding multimedia presentations in the real world. In: ISWC [2], pp. 79–86
8. Klein, G., Murray, D.: Parallel tracking and mapping for small ar workspaces. In: Proceedings of the 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality. pp. 1–10. ISMAR '07, IEEE Computer Society, Washington, DC, USA (2007), `http://dx.doi.org/10.1109/ISMAR.2007.4538852`
9. Milgram, P., Takemura, H., Utsumi, A., Kishino, F.: Augmented reality: A class of displays on the reality-virtuality continuum. pp. 282–292 (1994)

[8] Diferenttial GPS

10. Möhring, M., Lessig, C., Bimber, O.: Video see-through ar on consumer cell-phones. In: Proceedings of the 3rd IEEE/ACM International Symposium on Mixed and Augmented Reality. pp. 252–253. ISMAR '04, IEEE Computer Society, Washington, DC, USA (2004), http://dx.doi.org/10.1109/ISMAR.2004.63
11. Newman, J., Ingram, D., Hopper, A.: Augmented reality in a wide area sentient environment. In: Augmented Reality, 2001. Proceedings. IEEE and ACM International Symposium on. pp. 77–86 (2001)
12. Newman, J., Schall, G., Barakonyi, I., Schürzinger, A., Schmalstieg, D.: Wide area tracking tools for augmented reality. In: In Advances in Pervasive Computing 2006, Vol. 207, Austrian Computer Society (2006)
13. OGP: Coordinate conversions and transformations including formulas. OGP Publication 373-7-2 – Geomatics Guidance Note number 7 2, 131 (2012)
14. Sutherland, I.E.: A head-mounted three dimensional display. In: Proceedings of the December 9-11, 1968, fall joint computer conference, part I. pp. 757–764. AFIPS '68 (Fall, part I), ACM, New York, NY, USA (1968), http://doi.acm.org/10.1145/1476589.1476686
15. Wagner, D., Schmalstieg, D.: First steps towards handheld augmented reality. pp. 127–135 (2003)
16. White, S., Feiner, S.: Sitelens: situated visualization techniques for urban site visits. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1117–1120. CHI '09, ACM, New York, NY, USA (2009), http://doi.acm.org/10.1145/1518701.1518871
17. Wikipedia: Geodetic system - wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Geodetic_system (Agosto 2012)