Augmented Navigation in Outdoor Environments

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ABSTRACT
This paper introduces an augmented-reality system that provides navigation facilities, generation of itineraries and services delivery. The approach offers the possibility of combining real sceneries with digital representations of places of interest and services for a given itinerary. The first level of the approach supports the identification of a given place based on Augmented reality (AR), offering additional information (images and description) of that place. The second level generates navigation itineraries based on semantic Web services, user profiles and recommendations obtained from tourism sources. The experimental setup integrates smartphones with digital compass, GPS, camera and accelerometer. The framework has been experimented in Mexico downtown in the historical center "Zocalo". The applications are available in App Store and Google Play Store called "Turicel aumentado" and "Turicel2", respectively.

Categories and Subject Descriptors
D.0 [General]: Location-based services. H.2.8 [Database Applications]: Spatial databases and GIS. H.5.2 [User Interfaces]: Graphical User Interface

General Terms
Algorithms, Design, Experimentation

Keywords
Outdoor navigation, Augmented Reality, Location-based services

1. INTRODUCTION
The development of navigation and decision-aided systems for human navigating in urban environments is a non straightforward research issue as the research dimensions to consider range from spatial cognition, conceptual modeling, human-interfaces to positioning issues.

Nowadays, tourists visiting cities lack of technological tools that facilitate the search for optimal itineraries. For example, when searching for some places of interest, such as the location of a business or cultural landmark, an optimal route should take into account not only network constraints but also user profiles and preferences. The prototype presented by this paper introduces a mobile application with the following capabilities: 1) identification, localization and display of places of interest in the user neighbourhood 2) search for places of interest, based on a semantic-based processing of user preferences and habits 3) navigation and Augmented Reality (AR) facilities that combine route itineraries with additional views. Nowadays, AR enhances the way a tourist can interact with a real scenery. For example, a tourist might use a smart phone to explore surrounding places of interest, where virtual objects are overlaid on top of this scenery. These virtual objects can represent cultural attractions or specific urban sceneries. AR technology augments the sense of reality by superimposing virtual objects and cues upon the real world in real time [1]. AR has been the object of increasing development in outdoor and indoor environments [2, 3, 4]. One of the most important issues is to identify a landmark from a real image taken from a mobile interface. This leads to a pattern recognition problem where landmarks can be identified from a given scenery using appropriate algorithms. Then, navigations can be complemented by direction information using appropriate symbols [6], and even in combination with guided itineraries this being the scope of the research presented in this paper. However, such a close integration of real and virtual worlds implies to also take into account the user dimension as suggested in previous work [5], this being an aspect also addressed by our paper as well as user preferences and feedbacks.

The experimental system presented in this paper introduces an AR setup developed for navigation in the downtown of Mexico City with several services for tourists navigating in an urban environment. The navigation interface represents the first layer of our framework, the second layer is given by location-based functions combined with AR. The navigation interface provides route finding services augmented by virtual information (e.g., landmark pictures) in order to facilitate user navigation. The second level offers local views where the user can select one of the object/view presented by the global view, and/or moving to that given place or landmark in order to explore and view the shape of that place or landmark. The prototype is a mobile application that guides the user from a street to some specific points of interest with a search function (e.g., cultural places), and additional services that complete real sceneries by visual information. In both cases, virtual information is displayed over a real scenery captured with the camera of the smart phone. The remainder of the paper is organized as follows. Section 2 introduces the main principles and functionalities of our approach while section 3 describes the navigation infrastructure and the experimental interfaces and services developed so far. Section 4 concludes the paper and outlines further work.

2. FRAMEWORK PRINCIPLES

Navigation functions offer the users the possibility of generating route directions in the environment with additional information such as augmented views while she/he is walking on the street. Our underlying navigation model is based on a hierarchical graph where street segments are considered as edges, and connections between them as points of interest and nodes.

Itineraries are processed semantically and modeled as paths, including schedules, suggestions for visits, and exploration of a particular landmark using AR functions. All navigation task operations are supported by an orientation and location scheme, using a combination of sensors: GPS, camera and compass of a 3G cellular phone. Navigation functions of the first layer are provided as follows. When a user requests additional information regarding a possible route using her/his current position, a set of possible routes is displayed using arrows within icons over a real scenery (e.g., see Figure 1).

Figure 1. Augmented navigation view from iPhone

The second layer of the approach combines search functions with AR. The idea behind is that when a user wants to get some information about a given landmark, this user points to a particular landmark and get relevant and descriptive information. This implies to locate appropriately those landmarks using a marker-based approach, compass regarding orientation and GPS regarding the location of the user.

The former requires an instrumentation process, this means that landmark markers are previously captured and stored. Markers are photos or images that can be detected and recognised by the AR application, in order to identify cultural objects on top of which virtual information should be displayed.

Moreover, the identification of his position and orientation relative to the observer is obtained, this process is supported by a combination of augmented reality libraries: NyARtoolkit (http://nyatla.jp/nyartoolkit/wp/) and Vuforia (www.qualcomm.com/solutions/augmented-reality).

Furthermore, the identification of a marker is used as an additional mechanism for calibrating the position of the user. In fact we consider that GPS is error prone, then when a markers is identified, the location of the user can be improved as the location of that marker is previouly stored with high precision. The identification of the landmarks has been made by an image recognition process where each landmark was photographied, vectorised and then modelled as a placemark. All the points identified by the vectorization process are points of high contrast in the neighbourhood (Figure 2).

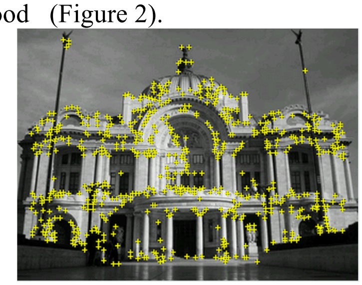

Figure 2. A trackable image of placemark (i.e., placemarker)

As seen in Figure 2, the image exhibits several yellow dots that constitute the skeleton of the placemarker. The whole process has been performed with Qualcomm (Mytrackeables, 2012).

3. FRAMEWORK INFRASTRUCTURE AND EXPERIMENTAL INTERFACES

The framework development and experimental interfaces support several functionalities: 1) panoramic view, to explore a real scenery using the camera's cell phone, 2) search by area, to find an area and associated services as well as the landmarks of interest associated, 3) itinerary generation, including route generation and landmarks description. The framework flow process is as follows. First the camera phone makes a focus on the given area of interest. Next a quadrant detection or sensors process are performed in order to distinguish the landmark, building or area targeted. Once detected, the area or landmark, the location and direction the user is pointing to is established. The landmark identification is used only when a marker is identified. Users can then navigate and request the information associated to different points of interest while the environment exploration is initialized. Information retrieval is performed making connections with a local database and web services (e.g., Google maps, Wikipedia, etc). Real images captured and virtual data are combined to be displayed on the cell phone. On-screen information is divided into several areas, sharing the screen space using sliding components. The AR view is shown when the user touches in any buttons in the navigation bar, and when the smartphone is in horizontal position. The menu interfaces offer several services: environment exploration and navigation, search of places and itinerary generation.

3.1 Orientation and location scheme

A location and orientation scheme has been developed in order to support itinerary generation and navigation tasks. Points of interest previously identified in the streets of downtown (so-called Zocalo) are captured and stored locally and manipulated using SQLite (http://www.sqlite.org). The location schema takes into account several geometrical and orientation data: 1) real world coordinates previously captured, current position of the user, and coordinate system of virtual objects 2) projection angle from which the scenery is captured and 3) camera-based coordinates of the landmarks identified in the real scenery. This allows tracking the landmarks identified in the camera scenery, and any change of position and orientation of the user.

The camera is configured in landscape mode (horizontal or vertical) in order to process correctly the different coordinate systems (GPS, compass and virtual objects shown on the graphical interface). A match among these coordinate systems is identified, that is, between virtual objects (OpenGL: http://www.opengl.org/) and the real environment. When no marker is available, the system uses sensors (GPS and compass). The bearing is identified and refers to the angle generated from the origin to the reference points. The sensor compass is used to guide the user. The coordinate system of the compass is projected on one plane. Overall, GPS and compass provide location-based data regarding the landmarks identified in the real scenery, while OpenGL supports the integration of virtual objects in the real scenery. Those data are integrated into a position-orientation-3D algorithm that locates the virtual object.

Additionally, when a tablet is used, three possible positions are available to identify the places: (1) the hands above the head (the bottom of the device must not exceed the head). (2) display of the mobile device in front of the user's face and (3) hands at stomach with the device screen pointing to the sky. All positions direct the mobile device in one direction. The position-orientation-3D algorithm consists of the following steps:

1. *Get the user's current position*
2. *Process the benchmark target being evaluated*
3. *Make a query to the database to obtain the coordinates of the sites of interest*
4. *Calculate the distance between two points and get the bearing.*
5. *Turn the compass and set the ladnscape mode to the results matrix*
6. *Draw a virtual object in OpenGL and process the matrix obtained from the compass to the OpenGL projection matrix*
7. *Camera view axis Z is used as the reference and the radius and the components X and Y are computed to integrate qualitative distances (far and near)*
8. *The reference system created is based on X Y axis that form a plane perpendicular to the Z axis (parallel to the view plan of the user)*
9. *Components are calculated and comparison with the bearing indicates the angle at which to draw the virtual object*
10. *Components in X and Y are calculated based on trigonometric values for the correct positioning of the virtual object*

3.2 Visualization and Itinerary Generation

The AR visualization can display previously stored images of the neighborhood using different modalities. The itinerary is generated using semantic processing combined with the Dijkstra algorithm. Semantic processing is used to define the relevance and role of a place involved in a route (i.e., this helps to decide if the place is included or not on the itinerary). The database contains data from several official sources: food and beverages (175 sites), takeaways and restaurants (1644 sites), nightclubs and bars (90 sites), historical sites (14 sites). Those places are classsified according to an ontology with 13 classes nested in 3 levels using an *hiperonimy relation*: Night places, Cultural Sites and Family places. The following figures illustrate the principles of the itinerary generation that combines a route finding process with route description and visualization. As shown in Figure 3, while a user is exploring a street, appropriate icons appear on the screen and present additional information (e.g., landmarks). Interaction is possible (e.g., changing the type of itinerary), and route directions are displayed (e.g., to turn left to reach a historical place).

Figure 3. Generated Itinerary (android view)

Figure 4 shows an example where icons of cultural places are overlayed on a real scenary on top of an iPhone 4s device.

Figure 4. Street navigation with AR view (iPhone view)

In order to provide additional locational information to the user (e.g., name and description of points of interest, estimated distance to reach a goal) when a user selects an icon, (e.g., Hemiciclo a Juarez, left side of Figure 4) the view changes and shows a set of images of the place with additional semantic information (Figure 5).

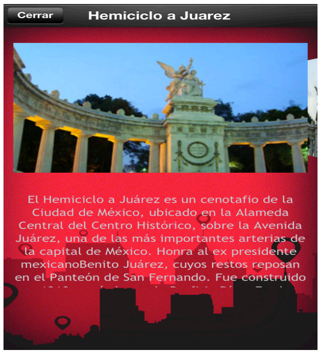

Figure 5. Additional information on a placemarker (view from iPhone)

Figure 6. Equalizer augmented view

Figure 6 shows the interface that suggests several possible landmarks in the user neighborhood. To the right, one can see a slidebar to increase or decrease the distance radius to show some places of interest (when the distance increases more icons are presented but buy taking into account display constraints). Moreover, when a user wants to find a place of interest, and when the system is suggesting a route, the user can ask for additional landmark information along the route generated in order to identify other sites of interest. Those are overlaid on the real scenery on demand or displayed on a map view using the Google maps interface.

Those experimental developments have been tested using iPhones 4s and Android tablets version 4.0. The work is still under progress to integrate additional landmarks and points of interest on the first square of the city. A panel of 40 users have experimented the system. They were all given some intuitive scenarios to follow. The functionality with major preference is the augmented view and display of historical information combined with itinerary generation. Still the range of possibilities is relatively large, and requires extension of the framework towards a larger area of the centre of Mexico city. Regarding the computational experiments, battery consumption in the smartphone is still a factor to improve, considering that power processing is considerable when combined with a simultaneous use of compass, GPS and camera. Indeed, better performance results will be achieved when the efficiency of the pattern recognition and AR algorithms will be improved. This means that combination of graphics generation with AR libraries results in a high battery consumption, thus leading to a relative small autonomy that does not guaranty long navigations.

4. CONCLUSION

We introduced an augmented-reality experimental design and prototype for navigation and generation of itineraries in urban environments. In constrast to previous work, this prototype provides a new form of navigation by combining real sceneries with digital images of the environment, and retrieval information based on a generated itinerary. The system developed has been tested on Mexico city in the square called "Zocalo". Evaluation results are encouraging as most of the users that have tested the system are generally rewarding the whole system regarding computational performances. A main issue still to improve is the recognition process in poor visibility conditions. Current and further works are also oriented to additional validation of the orientation and direction algorithms, and extension of the system by voice command assistance.

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6. REFERENCES

[1] J. Carmigniani, Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., and M. Ivkovic. Augmented reality technologies, systems and applications. *Multimedia Tools Appl.* 51, 1, 341-377, 2011.

[2] Lee J-Y, Lee S-H, Park H-M, Lee S-K, Choi J-S, Kwon J-S (2010) Design and implementation of a wearable AR annotation system using gaze interaction. *Consumer Electronics (ICCE)*, 2010 Digest of Technical Papers, pp.185–186.

[3] Arvanitis T.N., Petrou A., Knight J.F., Savas S., Sotiriou S., Gargalakos M., Gialouri E. (2009) Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. *Personal and Ubiquitous Computing* 13(3):243–250.

[4] Feng Zhou, Henry Been-Lirn Duh, and Mark Billinghurst. 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. In *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality* (ISMAR '08). IEEE Computer Society, Washington, DC, USA, 193-202

[5] Si Jung Jun Kim. 2012. A User Study Trends in Augmented Reality and Virtual Reality Research: A Qualitative Study with the Past Three Years of the ISMAR and IEEE VR Conference Papers. In*Proceedings of the 2012 International Symposium on Ubiquitous Virtual Reality* (ISUVR '12). IEEE Computer Society, Washington, DC, USA, 1-5.

[6] Höllerer, T., Hallaway, D., Tinna, N., and Feiner, S. Steps Toward Accommodating Variable Position Tracking Accuracy in a Mobile Augmented Reality System. In Proceedings of AIMS 2001: Second Int. Workshop on Artificial Intelligence in Mobile Systems, (2001), 31—37.