A Lightweight 3D Visualization Approach for Mobile City Exploration

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Abstract. Recent research has demonstrated the attractiveness of Mobile Spatial Interaction (MSI), the idea of accessing 3D spatially-related information and services with a mobile device. Even though impressive application prototypes in the field of mobile 3D city exploration have been presented, we identify several drawbacks preventing their wide-spread deployment on current mainstream phones. Introducing our project 'WikiVienna' and its vision of collaboratively built urban models based on user-contributed photos, we present a lightweight 3D visualization approach feasible for mass market phones. We describe our current implementation prototype and highlight upcoming research issues.

Keywords: Mobile Spatial Interaction, Mobile HCI, Rendering, Visualization

1 Introduction

In recent years, an extension of pure location-based systems can be observed to support more intuitive ways of exploring the nearby environment and interacting with spatially referenced content. HCI research has demonstrated the attractiveness and feasibility of interaction techniques that enable users to directly select digital information from their physical surroundings, simply by pointing at objects of their personal interest [13]. Also advanced visualization concepts such as the "Smart Horizon" [4], which foresees the mobile device screen as a window beyond the current visual field, have been deployed and tested with real-world prototypes [5]. On the market side, this trend towards Mobile Spatial Interaction (MSI, cf. [6]) is intensified by the advancement of the geospatial web (e.g. Google Earth) and the rollout of the latest mobile phones equipped with advanced features like built-in GPS receivers and digital compasses.

However, while spatially-aware technology and georeferenced data have not reached comprehensive coverage, how can the majority of today's users realistically profit from such new application ideas? How can we provide them with better visualizations than the traditional LBS-style 2D maps and generic Points-of-Interest (POI) collections? To address this question, we propose a lightweight 3D visualization concept that is technically feasible for the current telecommunications and content landscape.

The paper is structured as follows: In the next section, limitations in the light of today's device capabilities and infrastructures are highlighted. In Section 3 we introduce our WikiVienna server platform and its client applications. Finally, Section 4 concludes with the outline of necessary subsequent research activities.

2 Feasibility challenges for mobile 3D city exploration

As outlined above, most of the research prototypes introduced in the field of visual city exploration are only limitedly suitable for the practical use in the underlying tourism scenarios. We identified the following main issues:

Data storage and transmission. A detailed complete urban model requires a large amount of memory. Even if a tourist's mobile device is equipped with sufficient memory, the installation process is lengthened impeding an over-the-air-installation, and a later model update is not provided, respectively, as e.g. in [1].

Device fragmentation. Common 3D visualization approaches often do not take device fragmentation into account: a heterogeneous group of tourists is equipped with a manifold set of different mobile phones. Unfortunately, only high-end-devices provide operating systems enabling the development of native real time 3D applications described in [10] and [9].

3D model and content generation. The expensive task of 3D model generation is ignored in most research projects. Usually, a municipality either does not possess a detailed 3D model or does not make it available for free public use. Therefore, relatively small city fragments are often modeled manually by 3D artists resulting in expensive, static models which also cannot reflect e.g. seasonal or architectural changes over time [1,2,12]. This problem is partly addressed by free and easy-to-use modeling software (e.g. Google SketchUp) making 3D building modeling possible even for nonprofessionals.

3 The WikiVienna approach

The Austrian research project WikiVienna addresses the above challenges. To enable flexible content creation, end-users are reconstructing an urban model in a collaborative effort by contributing photos of the environment. To minimize data storage and transmission demands, the visual model is rendered on the server, and only information regarding the currently visible objects is sent to the mobile device. Client applications are provided as J2ME midlets with dynamic device-aware adaptions to ensure the best possible support by mainstream phones.

WikiVienna's current system architecture is depicted in Figure 1. The server-side platform consists of a central mediator offering the necessary services via HTTP to the mobile clients and two servers for the basic tasks of model reconstruction and rendering as well as for visibility calculation and POI selection. The platform also integrates additional external web services providing 2D map tiles and geocoding functionality. Two client applications enable the contribution of content by users and the exploration of the urban model, respectively.

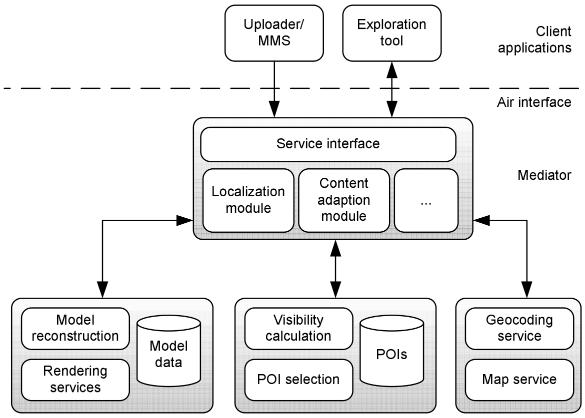

Fig. 1. WikiVienna's system architecture

3.1 Server Platform

The platform comprises services for the following tasks, each provided via the central mediator interface:

Management of user-generated content. Participants may contribute multimedia data such as text messages, taken images and recorded audio files via a small J2ME application or alternatively, via MMS. This data is stored in a spatial database together with its metadata such as the location, the creator, suitable user-specified tags and a verbal description.

Collaborative reconstruction. Submitted photos are provided to the reconstruction server and from each one a sparse set of unique feature-points is extracted. These feature descriptors are kept in a tree-like structure allowing a fast retrieval in order to recognize pairs of matching photographs. Once multiple pictures with correspondingly matching features have been established, the extrinsic (i.e. position in 3-space) and intrinsic (i.e. focal length, lens distortion) properties of their cameras can be basically determined. According to the epipolar geometry, having the camera coefficients, the 3D positions of the corresponding 2D features in the photos can be computed. The application of such a matching procedure generates a cloud of 3-space points, which serves as input for the reconstruction of the buildings' facades [7]. These facades, enhanced by textures sampled from the original photographs, provide the incremental model which serves as a source for further renderings. In a preliminary step, we are using an existing block-model as a projection surface for user-submitted photos.

Device-aware on-demand rendering. The server hosting the reconstruction process and the urban model provides a service returning a rendered cylindrical panorama image at the passed position. A component responsible for the device-aware content adoption determines the service parameters such as the image height and the compression rate based on device profiles.

POI Selection. Currently, we build upon a visibility engine developed in a former project at ftw. [13]. Given the current location, the resulting Local Visibility Model (LVis) contains the visible POIs' names, types, the distances and angles in relation to the user's position, etc.

3.2 Exploration tool

The development rationale for the exploration client is to provide advanced visualization techniques beyond static 2D map- and list-based visualizations for a broad audience.

Advancing visualization

We aim at further exploring the "Smart Horizon" concept, which considers a mobile device as a virtual window beyond the user's current field of view [4]. Departing from a state-of-the-art Smart Horizon system, a recently field-tested restaurant finder for the inner city of Vienna [5], we explore several new conceptual design ideas that could be beneficial in city exploration. Figure 2 depicts the evolution of the Smart Horizon concept we are envisaging in this work.

a b c

Fig. 2. a) Panorama view of an untextured 2.5D block model, b) Panorama view of the untextured 3D model (handcrafted) c) sketch of the planned panorama view using the textured 3D model automatically reconstructed from user-generated photos

In the restaurant finder (Fig. 2a), the environmental objects were represented by untextured 2.5D blocks that have been automatically generated from mobile operator network planning models. While these simple models can already well accommodate relatively easy restaurant identification tasks [5], it seems worthwhile to better understand in which regard full 3D modeling and building textures are needed for broader or more complex tasks. Fig. 2b shows the currently implemented prototype, displaying fully shaped, but untextured 3D objects from a handcrafted city model. A sketch of a potential result from the new collaborative reconstruction rendering algorithms is provided in Fig. 2c.

Another conceptual design aspect addressed by the WikiVienna client is to optimize the virtual information overlay over the environmental model. The icons are semitransparent to avoid an annoying occultation of the rendered scene. Pressing the phone's 'select' key, information about the currently active POI may be fetched. The active POI is always the one nearest to the screen's center and the only one drawn nontransparent. In order to help users to get an overall view of the surroundings and to improve their navigational performance, the respective map portion can be optionally displayed. The application allows map rotation according to the panorama's current visible part, thereby enabling 'forward-up equivalence', a well established design principle in virtual navigation [3].

Enabling widespread use

To meet the major requirement of mainstream phone support, the exploration client is implemented with J2ME featuring several device-aware features. Via the mediator's HTTP interface, the tool separately fetches the different parts forming the final user interface, namely the remote-rendered panorama image, the list of currently visible POIs with their distance and angle and the corresponding 2d map tile.

For positioning, an available GPS device can be used, or alternatively the user can submit his current location by providing a street address. On older mobiles we show the user's current viewing angle in form of a triangle on the static map instead of the memory and computation intensive image rotation. Scrolling the panorama is supported via the numerical keys or via possibly built-in acceleration sensors by tilting the device. The most intuitive interaction is possible if a digital compass is available enabling an automatic rotation according to the user's turn [5].

4 Conclusion & Future work

We introduce a new approach for mobile city exploration that can be instantly realized with mass-market mobile phones. Visualization, input and positioning methods are optimized according to the varying mobile device capabilities. An end-user generation approach is developed to accelerate 3D environment model construction and annotation. Using the collected meta-information, we will build up a multipurpose database, covering global location, visual response, as well as semantic information related to surrounding objects.

Regarding visualization, the techniques to present both spatial focus and context should be advanced, thereby refining recently derived design guidelines [5]. The combined map-panorama view presented in this paper should be compared to a bird's eye 360° surround view, which has so far been found to be most preferable [5].

Furthermore, insights from user studies regarding the appropriate degree of realism of the scene visualization should be fed into the reconstruction algorithms. The benefits of higher visualization fidelity should be assessed. In particular, those texture details need to be identified that are essential for specific orientation and interaction tasks.

Related to this is the design of the virtual information overlay, which should not mask or mismatch with the underlying spatial scene. The proposed combination of non- and semitransparent icons therefore needs to be evaluated for each of the mentioned forms of scene rendering. Of course, the relevance of different types of meta-information (e.g., street names, directions, POI) needs to be considered in the design of the virtual information overlay, also taking into account the experiences gathered with other, not yet spatially-aware city exploration systems (e.g. [1,11]).

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