THE CREATIVE HISTORIES MOBILE EXPLORER – IMPLEMENTING A 3D MULTIMEDIA TOURIST GUIDE FOR MASS-MARKET MOBILE PHONES

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In this paper, we present a mobile tourist guide application prototype that helps tourists to explore a historical site by offering them an interactive 3D visualization of the environment. Tourists can retrieve media clips and text-based content related to locations in their vicinity by selecting them in the 3D view. An intuitive user interface helps them to personalize the content offering to their specific interests. An additional interface element – the "timeline" slider – can be used to change the appearance of the 3D model so that it represents different historical epochs. This way, tourists can interactively explore what their surroundings looked like in the past. Unlike in comparable efforts, the application is not restricted to a specific high-end PDA or pen-based PC. Instead, it is designed to run on standard medium-range mobile phones and to be portable across device models. The paper summarizes the lessons learned during the implementation of the prototype. It discusses the general possibilities and limitations of current mass-market devices with regard to multimedia guide applications and presents performance results for different technologies that are relevant in this context. The paper concludes with an outlook on future work and a parallel research activity that will use GPS and orientation sensors to synchronize the 3D visualization with the tourist's real-world field of view, turning the application into a virtual "window to the past".

1 Introduction

Multimedia tourist guide applications on mobile devices are a topic that is increasingly receiving attention from the research community. The technological advancements that facilitate this development are rather recent; the tradition of providing visitors of museums or cultural heritage sites with a handheld tour guide, however, reaches far past the times of personal digital assistants and tablet PCs. Museum audio guides have been in use for almost 40 years. They evolved from reel- to tape and eventually compact cassette-based systems to digital RAM, MP2 and MP3 systems [16]. The next evolutionary step is now the transition from audio-only to multimedia guides: The GUIDE system for the city of Lancaster [7], the trial hypermedia guide for the Costa Aquarium in Genoa, Italy [4], the Tate Modern Multimedia Tour pilots [15] or the Vincent van Gogh multimedia tour in the Van Gogh Museum in Amsterdam [21] are just a few examples of trial systems and systems in actual commercial use at museums and tourist locations worldwide.

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Meanwhile, recent years have brought a dramatic increase in the proliferation of powerful mobile phones. Enhanced multimedia features such as high-quality displays, cameras, advanced sound output and even 3D graphics capabilities are turning these devices into sophisticated personal information and entertainment terminals. Their processing power and memory size is beginning to rival that of desktop computers of just a few years ago. Their ability to establish data connections anytime and anywhere enables complex networked applications. Furthermore, mobile phones are distinctively personal devices: Their users carry them with them most of their time and have typically developed a certain familiarity using them. These properties make mobile phones inherently well-suited for applications that support users while they are on the move and which involve delivery and playback of different types of interactive and non-interactive media – two characteristics that are typical for applications in the tourism domain.

Several projects have investigated the topic of mobile multimedia guides, as well as novel interaction concepts for improving the intuitiveness and ease of use of such systems. Less work has however been dedicated to evaluate the technological options for making mobile guides available to a mass audience by designing them for cross-platform portability. In this paper we report on the engineering issues involved in the implementation of a networked multimedia tourist guide for contemporary mass-market mobile phones. The paper is organized as follows: Section 2 discusses related work. Section 3 introduces the Creative Histories project, a research project that addresses multiple research issues from the area of cultural heritage preservation and cultural tourism. In particular, it presents the Creative Histories Mobile Explorer, the mobile multimedia guide application developed as part of the project. Section 4 presents the results of the implementation phase. Section 5 concludes with an outlook on future work.

2 Multimedia in Cultural Tourism

Several studies have investigated the effectiveness of multimedia in a museum or tourism setting. Economou [8] evaluated a stationary multimedia application installed at an archeological exhibition and researched how multimedia impacts the way visitors explore a museum. She found that the novelty of the technology attracted people with no prior knowledge of or interest in the subject. Interestingly, she also found that the time users spent with the presentation did not affect adversely the time they spent in the rest of the exhibition. The application in fact encouraged them to explore and engage with the subject more intensively. Bellotti et al [4] presented user test results from a mobile hypermedia guide, realized on a personal digital assistant (PDA). They compared their guide against a traditional audio guide and deduced from their experiments that the audio guide supported a more effective learning process, but also drew the visitors' attention away from the real exhibit, while the multimedia guide encouraged them to improve their observation.

In the last years, virtual reality and 3D visualization technologies have entered the cultural heritage domain. The term *Virtual Heritage* refers to the use of these technologies for the preservation, interpretation and communication of cultural and natural history [18]. Consequently, museums and cultural heritage sites around the world have begun to complement their exhibitions with 3D multimedia terminals and kiosks [10], [12], [14]. Recently, a number of projects have also investigated the possibilities for incorporating 3D graphics into mobile guide applications. Most projects have so far focused primarily on the use of 3D graphics to support navigation. Rakkolainen and Vainio [17], for example, presented a 3D city guide that supports mobile navigation with life-like on-screen 3D models. They found that users perceived 3D representations as more recognizable than 2D maps because the visual similarity with reality helped them to find places in real life more easily. Laakso et al [11] evaluated the usability of 3D dynamic maps for access to tourist information. Unlike other projects, they also presented versions of their system for a Pocket PC PDA and a high-end smartphone. Burigat and Chittaro [5] presented a prototype 3D tourist guide application on a PDA. Their system uses GPS to present a location-aware 3D visualization of the currently visited area. The application also offers the possibility to retrieve information about nearby objects by selecting their representations in the on-screen 3D view. The retrieved information is, however, only delivered in textual form and no additional media types (such as audio or video) are supported.

3 Creative Histories – The Josefsplatz Experience

The work presented in this paper has been carried out as part of the *Creative Histories – The Josefsplatz Experience* research project [19]. The project addresses multiple research issues: The first goal is to produce a high-quality three-dimensional re-creation of the *Josefsplatz*, a cultural heritage site in the center of Vienna, Austria. The re-creation is generated from historical imagery, using a method that requires a minimum of manual intervention [20]. Associated with the reconstructed geometric model is a virtual information space: Media files containing historical images, photographs, audio documents, small documentary video clips or textual information are linked to different locations in the model. An interactive viewer application on a stationary terminal can be used to navigate through the model in real-time and access the associated media content by selecting the corresponding objects in the 3D view.

3.1 Creative Histories Mobile Explorer

In addition to the stationary application, a prototype mobile tourist guide was developed. The *Creative Histories Mobile Explorer* allows users to view the Josefsplatz model and navigate the media repository while they are on-site, using a standard medium-range mobile phone. Figure 1 shows the architecture of the Creative Histories Mobile Explorer system.

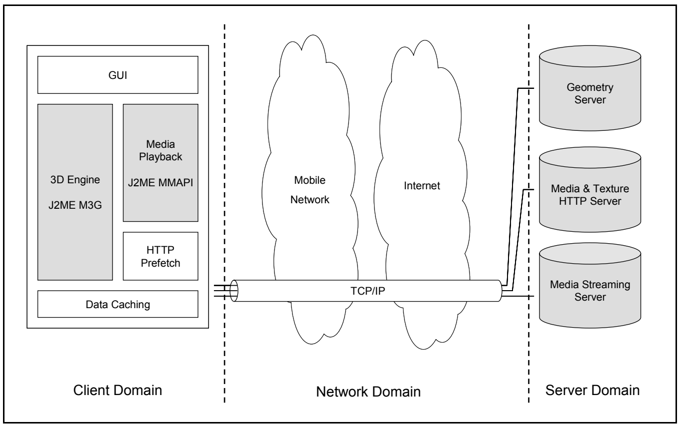

Figure 1. Creative Histories Mobile Explorer system architecture

The system consists of a set of servers and the mobile client application which connects to the servers over the Internet, using a GPRS or UMTS packet data connection. The key elements of the client application are the 3D engine and the media playback component. As will be discussed in Section 4, both are based on open standards that are supported across a broad range of mobile phones. The graphical user interface (GUI) is responsible for composing graphical output and handling user input. A caching and a prefetching component attempt to reduce the perceived download latency by avoiding unnecessary file re-transmissions and scheduling file downloads more efficiently. Three servers constitute the Mobile Explorer server domain: The geometry server hosts a simplified version of the high-quality Josefsplatz model, optimized for use on mobile phones. The media and texture server is a standard Web server which hosts the texture sets for the 3D model, as well as audio, video and text files. Additionally, audio and video files are available on an alternative streaming server. This way, the mobile client application can take advantage of media streaming capability on the phone, if available.

Figure 2. Creative Histories Mobile Explorer (left to right): 3D view, micro browser, category selection, timeline

Figure 2 shows four screenshots from the application: The main user interface component is an interactive 3D view that is navigated using the phone's joystick or 5-way-controller buttons. Whenever media content is available for the object that is currently in the center of the view, icons are displayed at the bottom of the screen. Selecting one of the icons starts playback of the corresponding media file. The application also contains a basic micro-browser for text information. Two fly-out overlay menus that can be activated with the left and right soft keys, and which slide in over the 3D view, allow the user to manipulate application settings: The right fly-out menu is used to select among different topical categories. The selection filters the media offering, so that only media files related to the selected topic are indicated to the user. The left fly-out menu contains the *timeline*, an interface element that influences the appearance of the 3D model. Setting the timeline to another year changes the texture set of the model so that it reflects the constructional state of the Josefsplatz in (or around) the selected year. The texture sets for this purpose were derived from historical paintings and drawings, the oldest one being a copperplate etching from the year 1560.

4 Implementation

It was a key requirement of the Creative Histories Mobile Explorer that it should not be confined to a single, high-end target device or mobile PC. The project should demonstrate the feasibility of realizing a 3D multimedia tourist guide on mass-market equipment, portable across phone models. As the base technology for our application, we therefore chose the Java 2 Micro Edition (J2ME). J2ME is the currently most widely deployed mobile application platform, with an installed base of more than 1.5 billion enabled devices in the year 2004 [2]. The majority of J2ME-enabled mobile phones also support a varying set of optional extensions, offering e.g. media playback, access to messaging, Bluetooth connectivity or 3D graphics capabilities. Basic guidelines for designing optimized cross-platform applications with J2ME are found in [13]. In this section, we discuss further important issues encountered during the implementation of our prototype and propose generally applicable solutions for addressing them.

4.1 Media Playback with J2ME

Playback of audio and video in the Creative Histories Mobile Explorer is based on the J2ME Mobile Media API (MMAPI). The MMAPI is an optional J2ME extension that provides support for time-based media and is available on most J2ME-enabled phones on the market. The two key challenges identified during implementation are *download latency* and *inconsistent format support*.

Download latency. Data rates achieved over today's 2.5G or 3G mobile phone networks are well suited for the low-latency download of small-sized files in the range of a few kilo bytes. Much of the data transferred between the Creative Histories servers and the mobile application falls into this category, e.g. 3D geometry data or texture images. Digital audio and video files, however, are typically much larger in size, ranging from a few 10 to several 100 Kilobytes. Download times are therefore considerably longer and can seriously disrupt the user experience. Table 1 shows measured download times for different types of content on two different test devices. The test was repeated 10 times and performed for GPRS and UMTS, which offer a theoretical maximum data rate of 170 kbits/second (depending on device model) and 384 kbits/second, respectively.

Table 1. Observed file transmission latency (number of download samples = 10)

		GPRS			*UMTS*		
Test Device		min [s]	avg [s]	max [s]	min [s]	avg [s]	max [s]
Toshiba TS921							
9 kB	(texture bitmap)	3.88	5.91	16.02	1.31	2.55	7.58
44 kB	(30 second AMR audio clip)	8.85	9.73	11.98	1.87	2.73	6.00
432 kB	(46 seconds 3GPP video clip)	38.14	43.05	55.34	10.79	13.36	16.59
Nokia N70							
9 kB	(texture bitmap)	2.83	3.07	3.49	1.67	4.6	8.8
44 kB	(30 second AMR audio clip)	7.14	9.1	13.83	1.63	2.41	6.09
432 kB	(46 seconds 3GPP video clip)	60.55	69.93	82.88	12.48	14.4	18.03

We evaluated three approaches for reducing the impact of download latency on the user experience:

- *Progressive Download.* In this method, which is often used to deliver video over the World Wide Web, the client downloads the media file from a Web server, but already starts playback before the download has completed. None of our test devices supported progressive download. All MMAPI implementations downloaded the media files completely before playback started. To the best of our knowledge, this is true for all MMAPI implementations available today.

- *Streaming.* In this method, which requires a special streaming server, playback starts almost immediately. During playback, control messages are constantly exchanged between server and client. The server can react to changes in the link condition and adjust the transmission rate to ensure continuous playback. However, the MMAPI does not mandate streaming support. Only a minority of MMAPI implementations support the necessary protocols at the time of writing. In our trials, only the newest test device offered streaming support.

- *Prefetch.* In order to mitigate the unavailability of progressive download and the lack of consistent streaming support, we implemented an experimental prefetching module. The principle of prefetching is that the application attempts to predict which files the user is likely to access in the near future and preemptively download these files into a cache. The prediction is based on the user's media playback history and topical interests. A detailed discussion of the Creative Histories prefetching mechanism is, however, beyond the scope of this paper.

Inconsistent media format support. The fact that the MMAPI does not mandate support for any particular media format or encoding scheme introduces an additional problem: Depending on the device implementation, different encoding formats are supported. In our trials, only two media formats were consistently supported across all test device models (the uncompressed PCM WAV and the compressed AMR audio formats). In practice, cross-platform multimedia applications will need to offer multiple versions of media content in different formats and foresee a mechanism that dynamically selects the appropriate version depending on the client's capabilities.

4.2 3D Graphics in J2ME

The J2ME Mobile 3D Graphics API (M3G) is an optional J2ME extension that defines a programming interface for developing interactive 3D graphics on mobile phones. At the time of writing, M3G is supported on more than 100 mobile phone models, with numbers steadily rising [3]. As expected, the 3D rendering performance of current M3G-enabled phones is quite limited: Figure 3 shows three 3D scenes we used to conduct performance tests on three different devices. The first scene was a basic representation of the Josefsplatz, consisting of 51 triangles. The second test scene was model of a statue, consisting of 448 triangles. The third one was a highly detailed column, made up of 4573 triangles. Table 2 lists the frame rate performance on three test devices.

Figure 3. 3D test models: Josefsplatz, statue of Emporer Josef and column on Josefsplatz

Table 2. Frame rate performance on different test devices

Test Device	*Josefsplatz*	*Statue*	*Statue (untextured)*	*Column (untextured)*
Nokia 6630	15 fps	14 fps	16 fps	2 fps
Nokia N70	15 fps	14 fps	16 fps	2 fps
Toshiba TS921	24 fps	7 fps	9-10 fps	<1 fps

Technological advancements in the development of mobile graphics acceleration hardware are likely to eliminate the performance bottleneck in the near future [6]. For current devices, however, 3D geometry must be highly optimized for low triangle-count in order to allow for an acceptable performance, as the test results indicate. In our system, the models were simplified using a quadric-based polygonal surface simplification algorithm [9]. Some of the models (such as the Josefsplatz buildings) were also rebuilt manually to ensure optimum quality at minimum triangle count. Apart from insights in the rendering performance of today's mobile phones, our tests also revealed two additional bottlenecks that are relevant in this context:

Texture loading. The native M3G file format encapsulates geometry and texture data in a single file. We argue that this approach has a severe disadvantage for networked applications: When downloading a 3D file from a remote server, the geometry must be downloaded together with the textures before it can be displayed. Since textures can be quite large, the download can take a considerable amount of time. For the Creative Histories system, we therefore defined an alternative file format and implemented a progressive loading mechanism: Rather than loading the entire scene in a single chunk, the loader will first download (and display) only the geometry. It will then progressively download and insert textures into the scene, one by one. While the scene is being built, the application remains fully interactive, without introducing unnecessary delays for the user.

Heap size. Even though mobile phones nowadays feature memory sizes up to several tens of megabytes and more, the memory available to a J2ME application is typically restricted to a far smaller amount. The total memory assigned to program execution is referred to as heap size. While desktop PC graphics cards typically feature graphics memory in the range of 128-256 megabytes, the typical heap sizes of current medium-range phones are in the range of one to a few megabytes. The most noteworthy side effect of this limitation is the resulting limit for number and size of textures that can be used. Cross-platform 3D applications will therefore need to offer alternative textures sets in different sizes, or the capability to adapt textures dynamically, in order to serve client devices with different capabilities with optimum texture quality.

5 Future Work

Future work on the Creative Histories Mobile Explorer will address two issues: First, a series of user tests shall help us assess the usability and intuitiveness of our system. It will also provide us with additional insights regarding the performance of our prototype under real world conditions. As the second work issue, we will equip the test device with an external, custom-built sensor module. The module will be connected to the test device via Bluetooth and contain a GPS receiver, a digital magnetic compass and a two-axis tilt sensor. Based on the position data from the GPS, the heading measured by the compass and the pitch- and roll-angles measured by the tilt sensors, the Creative Histories Mobile Explorer application can align the position of the virtual 3D camera with the user's real-world perspective. The visualization on the mobile phone screen matches the user's true field of view, and the application essentially functions as a "window to the past" which allows the user to get an impression of what the current view would have looked like decades or centuries ago [19]. Figure 4 illustrates the planned "window to the past" concept. It also shows a first sensor hardware prototype, containing a magnetic compass and tilt sensors, which has been developed.

Figure 4. "Window to the Past" interaction concept and first sensor hardware prototype

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