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Abstract
Audio augmented reality (AR) has a long research tradition in the tourism industry. Audio AR tour guides for urban environments provide location-based, auditory information about nearby sights, minimising distractions from interacting with mobile devices and enabling users to focus on their new surroundings. In this work, we present the design, development, and usability evaluation of AudioTransit, an audio AR tour guide using the public transport network for exploring urban tourist sites with which we investigate the design and implementation of audio AR systems in tourism. Overall, the study indicates very good usability and an altogether positive acceptance of the concept of audio AR in public transport for tourism purposes.

Author Keywords
Audio augmented reality; public transport; tour guide; tourism; usability study.

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented and virtual realities

Introduction
Audio augmented reality (AR), a mature subfield of mobile AR, has a long research tradition in the tourism industry [2]. Audio AR tour guides for urban environments manage to

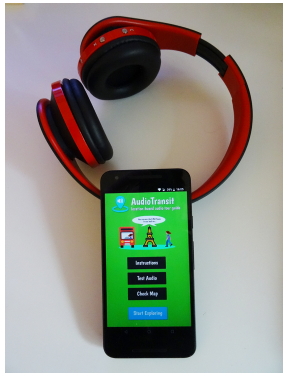

Figure 1: The AudioTransit tour guide system setup (main menu screen).

Figure 2: Using AudioTransit to explore Oslo on foot. The user approaches a place of cultural interest and an audio track with cultural information plays automatically.

provide location-based auditory information about nearby sights, minimising the distractions from interacting with mobile devices, and ultimately freeing the users' eyes to observe their surroundings and new environments [2]. Over the years, audio AR tour guides have found application in indoor settings (e.g. museums) [1, 17] and outdoor confined spaces (e.g. zoos) [12, 14].

Audio AR was recently used to support tourists' free exploration of open, urban environments, allowing them to plan their own routes based entirely on what they see and enjoy [2]. However, study results show that the possible combinations of familiarity and novelty sought by different tourists need further addressing; thus, along with the free unstructured exploration of urban destinations that audio AR can support, tourists may also require some kind of structure in their city tours [2].

Public transport can offer a structured touring experience, accessibility to almost all areas of an urban destination, and a variety of sensescapes that could essentially capture everyday life in a way that other modes of transport may not [6, 9]. Nevertheless, tourists are typically unfamiliar with and intimidated by the nuances of the public transport systems at the destinations that they visit [9, 10]. Mobile location-based services have been introduced in order to address this issue, and to facilitate smart transport methods for optimised routing and navigation when exploring urban destinations by way of public transport [13, 16, 5]. Mobile AR has also been used for transport-related informational purposes, e.g. informing travellers about vehicles' exact locations and arrival times [8, 7, 11].

Audio AR could be used in public transport for tourism purposes. This coexistence could benefit all fields by achieving a threefold goal: i) to provide tourists with alternative – structured and unstructured – ways of exploring urban destinations, based on structured improvisation [4, 2]; ii) to enable tourists to easily acquire useful cultural information about the visited area and experience unique interactions and sensescapes [2, 6, 9]; iii) to enhance the existing public transport network with value-added services while mitigating the congestion of urban transport networks and promoting urban sustainability and ecofriendliness [15].

In this paper, we present the design, development, and evaluation of AudioTransit (Fig. 1), an audio AR tour guide using the public transport network for exploring urban tourist sites with which we investigate the design and implementation of audio AR systems in tourism. This work extends our previous work on the AudioNear tour guide [2] and applies it in a public transport context. At this early stage, we design the main functionality of the audio AR tour guide, we develop a prototype, and conduct an empirical study examining the concept's feasibility and the guide's usability.

AudioTransit: An Audio AR Tour Guide

Functionality & Features

The AudioTransit tour guide offers a hybrid tour experience, suggesting routes that combine and support *free exploration (on foot)* (Fig. 2) and *structured navigation (by on-ground public transport)* (Fig. 3). When exploring, users put on their headphones, launch the AudioTransit tour guide application from their personal mobile devices (smartphones or PC tablets), and choose a preferred route. The route consists of parts that are explored on foot, parts that use public transport, and several places of interest (POIs). POIs can be *cultural* or *navigational* (Table 1). When users get within a specific, pre-defined radius of a POI, either by walking or by using public transport, a cultural or navigational audio track plays automatically (Fig. 4). Users can control the audio track playback with the headphones' mic button, so that interacting with the guide's graphical interface is

Figure 3: Using AudioTransit to explore Oslo by tram. User gets cultural information about the surrounding area.

Cultural POIs: Sights and city areas of cultural interest that trigger audio tracks with cultural information, e.g. history, architecture, visiting hours.
Navigational POIs: Places of navigational interest, such as bus/tram stops, that trigger audio tracks with practical, navigational information, e.g. bus/tram number, change of tram line, or the next stop being close to a sight.

Table 1: The two categories of POIs for AudioTransit.

not necessary in mobility settings (Fig. 2 & 3). AudioTransit also provides users with an assistive, interactive map of all the tourist sights for additional navigation purposes. At any time, users are able to check the map to locate the nearest sights and get directions on how to navigate towards them.

Design Rationale

The design of AudioTransit is inspired by the functionality of the hop-on hop-off tour bus. In general, these tour buses offer their passengers auditory location-based information about surrounding sights, allowing them to get off at specific bus stops and visit these sights on foot. Nevertheless, these means present certain weaknesses since they i) have limited spatial coverage focusing only on popular sights, ii) they do not support tourists' off-bus free exploration of the visited sights, and iii) they add extra weight to already congested urban transport networks, thus negatively affecting urban transport sustainability [9, 15, 4]. These issues are tackled in AudioTransit. AudioTransit uses on-ground public transport (e.g. bus and tram services) for navigating between several urban areas and as an environmental-friendly and sustainable way of touring, using the existing urban transport network. At the same time, the guide's hybrid functionality supports the free exploration of sights and continues to offer cultural information even when the user gets off the vehicle.

The main design goal of the AudioTransit service is to enable tourists to *explore tourist sites and get all the site-related, tourist information at one time and in one place*, so that they can "interpret" the environment and discover more about the cultural heritage of the visited place [2]. At the same time, this information should be delivered in an unobtrusive and undisruptive way so that tourists can focus on their surroundings; therefore, *minimising the distraction coming from the interaction with their mobile devices* is important [2, 12]. Audio AR was chosen as the most suitable technology to accomplish the main design goal while a series of important design decisions were made to minimise distraction. More specifically, AudioTransit was designed to work out-of-the-box upon launch through a simple and informative menu page (Fig. 1), without requiring extra user information or further adjustments. Interaction with the audio tracks was designed to take place through the headphones' mic button, so the user would not need to interact with the mobile device. The audio tracks were designed to be short and concise, with no sound produced when the user was not inside the radius of a POI (Fig. 4). That way, the user could still pay attention to the external, environmental sounds while exploring.

Another design goal is to implement *a robust spatial activation method for the audio tracks that also supports shared, multi-user tour experiences*. The tour guide should create a shared auditory and social experience and operate uniformly for users that are moving in groups (e.g. families) [1, 12, 2] while supporting two different mobility states, i.e. walking and using public transport. To fulfil the requirements mentioned above and avoid being bound by specific hardware (e.g. headphones for directional audio), we utilised a radius-based approach to define activation zones near the POIs (Fig. 4). The radius around each POI was strategically and manually placed so that it only contained areas where the sight was clearly visible.

System Implementation

The AudioTransit prototype adopts the back-end functionality of AudioNear as described in Fig. 4 and Section 3.2 of [2]. More specifically, AudioTransit was written in PHP and MySQL, using the AR Layar API (layar.com). The Layar platform enabled the development of the location-based, radius-activated audio AR experience and the map-based

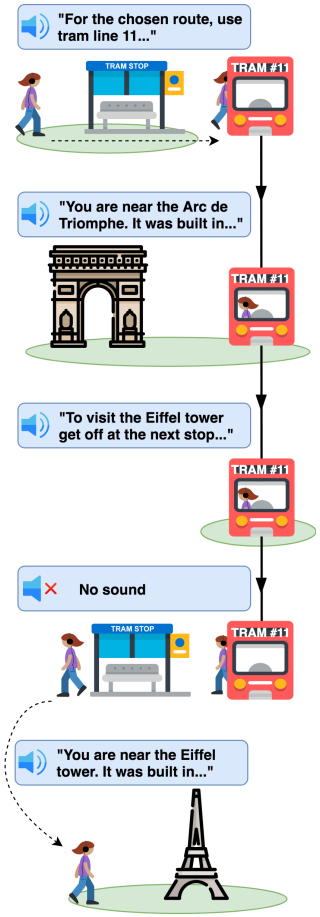

Figure 4: A usage scenario for AudioTransit with five different states in a route, displaying the radius-activated functionality for a user entering cultural and navigational POIs' radiuses (in green), either on foot or by tram.

navigation, also offering cross-platform (Android and iOS) capabilities. The prototype was developed as a web-based application, utilising a 4G broadband connection.

A circular route with 24 POIs in the Oslo city area was implemented in the AudioTransit prototype (Fig. 5). The Oslo public transport tram system, called Ruter, was utilised and two pilot testings of the guide en route took place to ensure its technical robustness. The duration of the audio tracks was around 60 seconds, based on user suggestions from our previous study [2]. The playback of the audio tracks was controlled by the headphones' mic button, i.e. tap button once to pause/stop playing track, tap twice to replay track.

Usability Study

To evaluate the AudioTransit prototype, a user study was conducted, collecting feedback on usability, technical issues, and suggestions for further development. First, a session with AudioTransit took place. At the beginning, participants installed the tour guide application in their mobile devices and were given a basic description of the tour guide's functionality. Then, they individually explored the circular route of the prototype (Fig. 5). Participants were entirely in charge of route planning and navigation while their touring route was recorded. After completing the circular route and the session ended, participants were asked to fill in the 10-item System Usability Scale (SUS) questionnaire [3]. Then, a semi-structured interview took place, asking participants about their experiences interacting with AudioTransit and discussing future improvements.

Results

Eight users (mean age: 33.38, SD: 1.51, male/female: 5/3) participated in the usability study. All participants completed the circular route, with a tour duration of between 144 and 202 minutes (mean duration: 177.75, SD: 21.22). All participants got off the tram to visit a sight at least once and then got back on it to continue the route. The prototype received a SUS score of 84.06 (SD: 5.66, range: 77.5-92.5), indicating that AudioTransit is placed at the high end of the SUS scale, achieving a "good" to "excellent" ranking [3], just like its predecessor, AudioNear [2].

At the interview, participants commented positively on the simplicity of AudioTransit, pleased by the fact that all the necessary information was delivered discreetly through audio and that they could focus on observing the environment. They were also satisfied with the guide's technical performance regarding the successful – in time and in place – triggering of the audio tracks while they found the map-based navigation to be useful and easy-to-use. On the negative side, users were sometimes tired of wearing headphones and they may have missed out on auditory information. To that end, they suggested adding vibration to notify when an auditory track starts playing, in case the headphones are off. Another suggestion was the integration of some sort of user feedback for the sights (e.g. ratings system, comments).

Conclusion & Future Work

Overall, the study indicated very good usability for AudioTransit and an altogether positive acceptance of the concept of audio AR in public transport for tourism purposes. The utilisation of public transport in combination with the free exploration capabilities that audio AR can offer [2], managed to enable a user-friendly, informative tour experience of urban areas and sights.

Our next concrete steps are to refine AudioTransit, adding haptic notifications (vibration), a sight-rating system, and three new tourist routes. Then, the user experience and usability of the new version will be evaluated with a larger

Figure 5: The route and the POIs of the AudioTransit study.

sample size. Overall, an iterative design process based on the collected user feedback will take place, leading up to a large-scale evaluation of AudioTransit in the context of tourist groups of two or more users.

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