4D Augmented City Models, Photogrammetric Creation and Dissemination

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Abstract. The availability of digital image repositories of historical photographs offers new possibilities to historians in their research. In addition to representing a large collection of data records themselves, image archives allow for new methods of research, from large-scale statistical analysis, to algorithmic generation of knowledge, such as historical 3D models, directly from these sources. In this paper, we explore methods to work with digital image libraries, from the creation of 3D or in extension time-annotated 4D models, to the eventual dissemination of research findings in teaching/learning scenarios. We review pedagogical approaches to reach different learning objectives, as well as methods that allow for the inclusion of historic city models employing Augmented Reality in mobile learning environments.

Keywords: Image Repositories, 4D City Models, Photogrammetric Reconstruction, Augmented Reality

1 Introduction

1.1 Image Repositories of Historical Photographs

Photographs are an essential source for historical research and key objects in eHumanities. Numerous digital image archives, containing vast numbers of photographs, have been set up in the context of digitization projects. Information and image retrieval with these extensive repositories is still challenging.

Digital image repositories meet a wide range of needs, from research in humanities and information technologies, through museum contexts and library studies to tourist applications. Architectural historians have developed various methods of analyzing both preserved and never-built or destroyed structures [9] in chronology and context. Style analysis, iconographic approaches and art sociological methods all address art historical questions. The tendency in recent research widens the focus towards a comprehensive view of art which can be supported by image repositories: The advantage of the new digitality consists in a large collection of pictures, but those repositories need to be equipped with special techniques that support art and architectural history research [6] as well as dissemination of its results. While working on urban history, issues with handling image repositories become apparent: First, the spatial frame of analyzed objects typically consists of large areas. Here, challenges while gathering, cataloguing and geo-locating the source photographies arise. Second, each source forms part of a specific time horizon, which means that often the scholarly examination will extend to several stages of urban development. The sources thus do not only need a spatial but also a temporal sorting. Computer based 3D and 4D models are helpful at this stage, as they allow to combine both components with the help of digital tools [32].

1.2 3D Models and their Temporal Expansion

Large image repositories are often used to generate three-dimensional models using photogrammetric methods [25,2]. The most commonly used technique is Structure-from-Motion (SfM) [35]. Here, a set of images which show one object is relatively oriented by automatically finding homologue feature points in two or more images. An algorithm to find these feature points is for example SURF [7]. After that, different filters are applied to get the most robust feature points, which are then represented by a descriptor. Using the relative orientation, 3D points of the photographed objects can be reconstructed.

In this paper, we present methods to adapt the SfM workflow on historical images. The images are taken from a large historical image archive and will be used to generate accurate *historical* point clouds. The topic of this research is also called historical photogrammetry [21]. To extend the spatial components of reconstructed point clouds with a temporal component, complex workflows are needed. First, a filtering of historical image repositories is required to include only photographs containing building information. The extracted dataset is subject to restrictions considering image quality, camera parameters, camera calibration and camera positions. E.g. the images are not taken at the same time by the same photographer or with the same camera. So the relative orientation of the dataset will be more difficult than in an usual workflow. If SfM cannot be applied to the images, different approaches may be tested like texture mapping or using additional current data [50,36]. So after this second step of generating 3D models the last step will concern temporal information. If models of different epochs exist, a deformation analysis can be applied. Furthermore, this relates to questions how many images of one epoch should be available for a successful reconstruction and whether it will be possible to generate models of completely destroyed or changed buildings.

A four-dimensional city model can be used for different applications. Scenarios include applications that allow researchers to browse through the images and get an extended visualization in a three-dimensional environment. This can be helpful to contextualize individual photographs and even uncover historical details [41]. Other end-user scenarios contain augmented reality applications in the field of tourism, allowing historical details and different epochs to be visualized right where the actual building has been in the past.

1.3 Knowledge Transfer in Cultural Heritage Scenarios

Knowledge transfer is an important issue related to cultural heritage tourism. Some common used traditional sources of information related to cultural heritage sites are paper-based guidebooks, real-life guided tours, brochures, location-based information panels or screens and audio-guides. The increasing use of mobile devices has created new ways for stakeholders in tourism to connect with travellers and mediate information about a cultural heritage site. There are a lot of mobile services for tourists to search for information on their target regions, destinations, restaurants, hotels, transportation and entertainment (e.g. *GeoTourist*, *Yelp*, *tripwolf*). In addition, digital libraries and archives (e.g. Europeana, Deutsche Fotothek) provide ubiquitous access to a large number of repositories (text, images, audio files) wich are interesting for visitors of a certain destination. Mobile technology has the potential to give access to the huge amount of information stored in digital archives and open new dimensions for knowledge transfer about cultural heritage sites. In particular, augmented reality applications can create digital overlays to the real-world environment and encourage users to explore and gain knowledge from a new perspective [47]. They provide access to travel-related information and relevant services anytime and anywhere [54].

In recent years, a lot of augmented mobile applications and toolkits were developed to enhance the tourist experience [33]. In the same time, there has been an increasing interest in applying AR to create unique educational settings [4] and especially cultural heritage sites became a field of interest for merging both issues.

Nowadays, facilities related to cultural heritage and tourism are increasingly looking for ways to enhance their visitors' learning experience [20]. Mobile augmented tourism applications are a promising approach to support knowledge transfer for educational purposes, while enhancing visitors' experience in cultural heritage settings [19,52].

2 State of the Art

2.1 Historical Image Sources

There are challenges for working with sources from urban history, as they always represent the view on the city, mostly an internal and thereby biased view. This leads to the essential responsibility of scientific research to take this fact into account for the evaluation and interpretation of findings, by contextualizing them in order to reach objectivity.

As a result, studies often consider only delimited time spans or narrow places. Through digital tools, an easier access to the sources and wider research focuses as well as improved opportunities of utilization are given, making a multi-focus analysis of the urban development possible. This leads to new research questions: How do buildings and cities change over time? In which contexts, such as political or formal developments, does a historical cityscape evolve? What similarities can be found between objects in terms of construction standards and requirements, building codes, regional, temporal or personal tastes and styles? Furthermore, what connotation did the buildings possess? Does the number of pictures taken of one specific building change over the documented time? Are there relations to other buildings or urban spaces given? Which interactions of architecture with other artistic genres, inscriptions or infrastructural facilities can be found? Which buildings are likely to form the architectonic background for social events such as demonstrations or celebrations? Against this background, digital libraries and computer based analysis tools are a great chance to overcome existing methodic boundaries both in urban history research and dissemination of research results.

2.2 Historical Photogrammetry and Fourdimensional City Models

Support through digital tools can be provided to answer the previously outlined research questions. The computation of historical 3D — or in extension time-annotated 4D — models forms a central part.

When considering the creation of a four-dimensional model with temporal and spatial components, three-dimensional models have to be created out of historical images. Falkingham et al. entitle this problem as "historical photogrammetry" [21]. A lot of different studies have been done using historical data to receive three-dimensional models. A simple approach is using historical images just for a modeling purpose [45,13]. So the geometric information is generalized and underlies assumptions. An extended modeling approach uses edge detection and afterwards monoscopic modeling to receive structure and color just from one image [38], [48]. Methods commonly used here are e.g. Single-View Perspective Imagery (SVR) or Texture Mapping [50].

For a complete reconstruction solely using the image information, SfM is usually applied. But in most cases, a completely automatic reconstruction fails and the point cloud does not represent the building very well. Hence, different recent studies use additional data (LIDAR, recent images, façade plans) of objects which are still visible today to support the SfM workflow [8,36]. Even touristic photographs can be helpful for a reconstruction [23].

The generation of a four-dimensional model requires the localization of the generated historical three-dimensional models. Researches have already been done on the reconstruction of a complete city using touristic images from online platforms such as flickr [44,1,34,25]. These models can be completed by the help of non-professional users through e.g. gamification approaches [49].

Extending these approaches with a temporal component requires data or models from varying moments in time. Kersten et al. use a wooden model and maps to reconstruct Hamburg in four epochs [30]. This technique is also used for other cities [26]. The project "4D Cities" coincides the most with our research question [41]. It organizes historical photographs, provides context and a semi-automatic 4D city construction tool for users.

These different research topics show the feasibility of our studies and the constructive steps towards a four-dimensional city model.

2.3 Mobile Augmented Reality

Stationary AR experiences (e.g. spatial AR, or stationary HMD-based AR) in museums and other installations, have enabled a first-person exploration of local and remote cultural heritage (CH) sites and contents. They also allow for an active inspection of and interaction with digitized artifacts, annotations of objects with rich multimedia elements conforming to interactive pedagogical approaches, and providing enhanced user experiences to visitors as well as advanced working paradigms to researchers. In these contexts, AR systems can be used to improve learning and interaction by providing self-guiding context aware media for presentation and interpretation of CH resources. With the emergence of affordable

Fig. 1: Augmented Reality view of the Dresden Frauenkirche

mobile computing systems, handheld AR has made its way into CH (see Figure 1). Even early AR applications in CH such as ARCHEOGUIDE [46,51,17] aim at a multitude of disciplines and research outcomes: Archaeological Research, Education, Multimedia Publishing, and Cultural Tourism, employing mobile AR for on-site visualization of reconstructed 3-dimensional virtual models of artifacts and buildings. In addition to the various benefits of stationary AR installations in museums or at archaeological sites, mobile computing devices, i.e. handhelds or wearables, enable personalization of content and experiences to the users, and facilitate collaboration amongst the participants.

2.4 Mobile Tourism Applications

In the recent decade, many cultural heritage tourism attractions like museums and art galleries enhance visitor's experience through augmented reality applications by using wearable devices [27,37,52]. Cities like London, Montreal and Chicago started to create location-based augmented reality city tours by providing special mobile tourist applications to explore and gain knowledge about the location and especially about urban history. *London Street museum* is one of the most impressing examples of the usage of augmented reality in urban environments. The visitor has access to the vast collection of historical pictures of the London Museum by using the application on their mobile phones in their current geospatial surroundings. Historical pictures and information available through the London Museums can be explored by pointing the camera to the present street view [39].

The development of this kind of application was driven and is still driven by the latest technological interventions in the field of Virtual and Augmented Reality, as well as by findings of related research fields such as Media Pedagogy, Learning Psychology, Technology Acceptance Research, Media Research, Information and Communication Technology, and Experience Design. On the one hand, these mobile augmented tourism applications as well as a variety of frameworks and toolkits (DroidAR, Layar, PanicAR) are based on research in these disciplines. On the other hand, they became an interesting field of research itself. The following findings of an initial literature review describe the current research in the fields of Taxonomies, User acceptance, Gamification and Learning Experience related to mobile tourism applications.

Taxonomy There are a few frameworks which classify mobile tourism applications in certain taxonomies by using different categories [28,29,54].

Kennedy-Eden et.al. [29] worked out a taxonomy of mobile applications in tourism to provide insights into application development trends as well as gaps in the mobile application landscape. They laid down seven categories for tourism applications: Navigation, Social, Mobile Marketing, Security/Emergency, Transactional, Entertainment, and Information. In addition, they investigated user interactivity. These taxonomies help to get an overview of different mobile tourism applications and to determine necessary services for future interventions.

User acceptance There has been done a lot of research in the field of user acceptance of mobile applications in general and several scientists specialized on tourism applications. Tom Dieck & Jung developed a theoretical model of mobile augmented reality acceptance in urban heritage tourism [19]. Others extended the Technology Acceptance Model (TAM) originally presented by Davis [18] through new aspects, i.e. perceived enjoyment (PE) and perceived mobility value (PMV), to enhance the explanatory power of the model for the acceptance of mobile learning [24]. To illuminate the acceptance of mobile tourism applications, these general findings can be transferred to tourists who access information about the destination (learning material) with their mobile device.

Another recent research work pointed out the factors that encourage tourists to actively use AR applications by doing a field study with 145 people in Deoksugung Palace, South Korea [14]. Goh, Ang & Lee [22] investigated tourists' desires and needs.

Gamification Despite the increasing adoption of gamification and its huge potential in tourism, research in gamification is still limited [43]. Gamification is assumed to motivate users to become more active, and is commonly implemented in commercial products [56]. It is a promising method to enhance tourist experience and learning and a current research interest related to mobile tourism applications. Recent research work by Xu et al. aim to explore the gamification trend and its potential for experience development and tourism marketing. Using a focus group, their paper discusses gaming and tourism, and explores what motivates tourists to play games [53]. Another publication describes how gamification can be used for attracting visitors' attention, arousing interest and generating the desired behaviour - visiting a particular destination [31].

Learning experience Research on learning experience and outcomes through mobile tourism applications is limited. Recent findings present a study on visitors learning experience in an art gallery using wearable devices [20]. Furthermore, results of a study investigating the increase of learning and sense of place for heritage places by using an AR mobile guidance system, indicates significant effects on learning and sense of place through the AR application [12].

3 Combination of Large Image Archives and Historical Data

As already shown, different approaches use recent large image archives for a three-dimensional reconstruction of cities or buildings. Other studies use solely selected historical images for a specific reconstruction purpose. In our work, we want to combine these two attempts to generate time-annotated three-dimensional models out of a large historical image repository. Within the studies, we make use of the photo library of the Saxon State and University Library Dresden (SLUB), aiming to use the generated models in both research tools as well as in Augmented Reality applications for dissemination of research results.

3.1 Filtering of Data

The photo library consists of 1.8 billion images from 87 institutions (6/2017). It is possible to search through the images by keywords or use given filters such as name of the photographer, date of recording, topic of the reproduction, people visible or time and place of creation. For a photogrammetric reconstruction, several different images need to show one (or more) buildings of interest from varying angles. Considering this purpose, an initial investigation into the material provided by the chosen library shows several challenges to the process of automatic reconstruction:

- Images are sometimes labeled incorrectly or the labels are missing.
- Keyword searches do not show images of buildings (Fig. 2) exclusively.
- Some images are not yet digitized with a high enough quality needed for the algorithms employed in digital reconstruction.
- Images have different illuminations or image errors.
- Images contain no color information.
- Images are not taken by the same photographer with the same camera at the same time, which entails the need for an external post-hoc camera calibration.
- All the available images of a building of interest often show the building just from a single position and angle.

Fig. 2: Variety of Hits for the keyword *Kronentor* (Crown Gate)

By now, the best method to get specific images is to look manually through different keyword searches and pick valid images for a three-dimensional reconstruction. E.g. for the Kronentor (*Crown Gate*) of the Dresden Zwinger the keyword search shows 875 hits and this image set was reduced to 44 images manually and subjectively [36]. This approach may be valid for one building/dataset but not for a reconstruction of a complete part of a city. It is also possible that some images were neglected due to missing labels or incomplete keyword search.

Consequently, an automatic image search and validation would be helpful in terms of a photogrammetric reconstruction.

Considering the different problems that were already shown, the filtering should be divided into different steps. At first images with a low resolution or poor image quality should be eliminated by certain thresholds. For the remaining images, a photographic processing in terms of illumination, contrast, and sharpness, would be imaginable. All these prefiltered images should then be divided in separate groups. One approach would be the splitting into the two groups *buildings* and *no buildings*. A possible method we will focus on is content-based image retrieval (CBIR) using a Bag-of-Features approach, and afterwards an image classification employing support vector machines (SVM) [16]. Classified images in the category *buildings* will then be used for a three-dimensional reconstruction. Wrongly classified images will be eliminated in the next steps.

3.2 Orientation of Historical Images

The next step towards a three-dimensional model, and a valuable tool for e.g. art historians, is the orientation of images related to a visible model. In photogrammetry, this is called the exterior orientation of the camera (position and rotation in space). Inner orientation describes the focal length and the coordinates of the principal point. Getting all these values is accomplished by using different photogrammetric methods.

The first approach we employed was a manual orientation of the images in the web application DokuVis [11] via Drag and Drop. This can be done for a few images but becomes time consuming for a large amount of data. So a direct linear transformation (DLT) was implemented into the system [10]. This photogrammetric method calculates the inner and exterior orientation of the camera in relation to given coordinates of a three-dimensional object and their homologue image coordinates. For the calculation, no approximation values are needed, but a minimum of six point pairs (which lie not in the same plane) have to be determined. So this method orients the images one by one semi-automatically, but is quite time consuming as well. In addition, a space resection could be applied with approximation values of camera parameters and just three point pairs.

In a next step we want to implement a photogrammetric bundle adjustment. This method calculates the inner and exterior orientation of a variable number of images of the same object. For this approach object coordinates of control points, their image coordinates and approximation values of unknowns must be given. Therefore, one or more historical images must show objects that are still present and can be measured at this moment in time. It will be also difficult to approximate camera parameters, because in most cases, the camera is unknown and the historical pictures were digitized so the resolution varies from the original size. For a fully automatic approach, homologue features in all of the images have to be found.

3.3 Three-dimensional Modeling

Different studies have already been done on getting three-dimensional models out of historical images. If there exist different views of one building it is possible to use modeling software to get 3D models of individual buildings. Historical maps, drawings and plans can easily improve the manual modeling. Nevertheless in the most approaches details get lost and structures are generalized [45]. Several studies even use current data to improve the modeling process [30]. Another solution can be applied for buildings, which are still visible today. The requirement is that the building didn't change too much. Even surrounding objects, that can be seen on historical photos are enough to support a reconstruction [8].

We want to get away from a manual modeling to an automatic reconstruction approach, so the geometric information comes directly from the images used. Methods allowing the reconstruction of three-dimensional models out of images are for example stereophotogrammetry or SfM. SfM is usually used to reconstruct objects out of one homogeneous dataset. For historical images, the algorithm has to be manipulated in order to achieve results. Possible manipulations are e.g. SfM with little overlap [40] or SfM using line geometry [5,42]. Further researches have to be done to improve the existing results.

3.4 Handheld Augmented Reality in Cultural Heritage

We have identified different types of data that are utilized in CH applications. These include data describing buildings and landscapes, various types of CH artifacts, images, labels, semantically annotated (rich-) text, audio, video and even animated creatures and human avatars representing historical population or other visitors. The datasets include 2D and 3D polygonal geometry that is either modelled manually, or reconstructed from acquired data such as pointclouds or images, automatically processed using methods such as close-range photogrammetry. 3D volumetric data generated by CT or MRT scans can also be included into the AR experience. Handheld AR techniques are utilized to strengthen the user experience in cultural heritage sites and installations by supporting spatial awareness, personalization, as well as to enable physical exploration of historic space.

AR applications treat data in two major different modalities, information that is registered and integrated into the environment on the one hand, and data that is presented entirely outside of the AR context on the other hand. The mode of presenting data does not exclusively depend on the type of data, instead, both methods are often used for the same type of data concurrently. For instance, photos and videos describing CH artifacts are often displayed alongside the augmented view. In some applications, spatially located photos, and even video, might also be presented as augmentation to the displayed reality. Similar observations can be made for the display of text as labels as well as complex annotations in augmented views, and as additional informational presentations external to the AR context.

Interacting with data in handheld AR applications has been studied not only in practical CH use cases, but also from design, human factors, and usability engineering perspectives. User centered design methods have been employed to guide design requirements from the user's perspectives. Various studies have been performed that evaluate touch- and gesture-based interactions both on the screen as well as observed by a mobile device's camera. While there are many applications that allow interaction based on spatial proximity to a given Point Of Interest, spatial interaction, i.e. interaction that is performed by spatially moving or rotating the mobile device, is not yet used in CH contexts.

4 Approaches to enhance visitors' experience and knowledge transfer

4.1 Tasks of tour guides relevant for AR application development

Tour guides are one of the key front-line players in the tourism industry. Through their knowledge and interpretation of a destination's attractions and culture, and their communication and service skills, they have the ability to transform the tourists' visit from a tour into an experience [3]. The success of the tourism industry depends on the performance of tour guides in each destination [55]. A tour guide provides assistance, information and cultural, historical and contemporary heritage interpretation to people on organized tours and individual clients at educational establishments, religious and historical sites, museums, and at venues of other significant interest. These traditional tasks should be implemented in mobile augmented tourism applications, which present location-based information about a cultural heritage site. Current AR applications provide a variety of different functionalities to meet these tasks. They give access to multimedia-rich environment through the use of various multimedia formats. Such formats range from sound and image to video clips, 3D models and hyperlinks that may direct the user outside the application [33]. They assist the tourist through navigation functionalities, offer different services like tickets, reservations and shopping and a few implement a creating, sharing, collaboration, communication or social component [29]. According to their functionalities, mobile AR applications in tourism can focus on service-oriented or knowledge-mediating issues. For providing a user-friendly and sustainable mobile tourism application a mixture of both is recommended to strengthen user acceptance. Providing assistance and information are well implemented tasks. One of the main problems within mobile AR applications is the missing interpretation of cultural, historical and contemporary heritage to people and missing pedagogical approaches to connect different disciplines like geography, architecture, art, history as well as cultural, economic, social facts related to a destination.

4.2 Pedagogical Approaches to enhance visitors' experience and knowledge transfer

There are different approaches to give visitors a unique experience in real-life city tours. A few of them are implemented in AR tourism applications, but there is still a huge potential in using pedagogical approaches to enrich AR applications for mediating knowledge about urban history or cultural heritage. Themed tours are one of the most common approaches, which are already adopted to AR tourism applications (e.g. *Chicago00*, *Timetraveler-App*). These applications give access to guided or self-guided tours under the aspect of a certain themes *The St. Valentine's Day Massacre* or *The History of the Berlin Wall*.

Another approach used in real-life scenarios are *scenic walks* or *theatre walks*, which are combined with drama. The guide slips into a role and leads the visitors to special places where other actors may live the events of earlier times to let. This kind is very similar to so-called *Ghost-Walks*, with ghost stories and legends in the foreground. These elaborately staged scenarios could be a model to implement in AR tourism applications. The development of mobile technology makes it possible to create digital scenarios, which make history become alive at certain locations. *Living History at Union Station* in Kansas City is a tourist application, which uses the principle of a theatre walk. This is a mobile augmented reality application using story telling. It takes users on a journey back through time as they take self-guided history tours that play out on their phones, as they explore the Union Station their own way. The application provides in-depth story telling within an augmented reality experience, before users can go deeper through written stories, images and artefacts [15].

To explore pedagogical and motivational approaches to enhance tourism experience and foster learning about a destination is one important issue for upcoming research. Investigate tourist responses to different pedagogical strategies within AR tourism applications and to illuminate motivational aspects and learning effects are an important part of this research. To unfold the potential of AR technology for the communication of urban history or cultural heritage it is indispensable to translate real-life approaches into digital scenarios, which can be implemented in mobile augmented tourism applications.

5 Implications

We have described the neccessary steps in a workflow toward automatic reconstruction of 3D models from historic image sources and the possibilities for their integration into mobile AR applications. The implications of our studies concerning the applicability of historical photographs in image repositories with respect to algorithmic reconstructions are manifold. We have touched upon the challenges of the usability of existing digitalized images in Section 3.1. Several of the introduced shortcomings, such as the image quality of scans, as well as incorrect labeling, have to be addressed manually. Other imperfections in the source material, illumination or missing camera calibrations, require algorithmic advancements with a special attention towards historic photography.

Hard problems still are the missing density of records in the source material, as well as very few dominant views even for well-documented buildings, which can make an automatic reconstruction impractical. Here, the addition of contemporary image sources can be a way to amend some of the problems in the documented record.

5.1 Four-dimensional Modeling

Time as a fourth dimension is an important factor in our work that ist not yet addressed in depth in previous approaches. Serveral different questions can be addressed in this matter. How many images are needed for one epoch? Is it possible to generate more than one historical model? Can a change in the building's appearance be visualized properly? Is it possible to reconstruct completely destroyed buildings?

5.2 Augmented Reality in Cultural Heritage Applications

The studies outlined in Section 2.4 confirm that there is an increasing research interest on the development, acceptance and evaluation of tourism applications, on generalized tourist needs and behaviour as well as on tourists' desire. All mentioned research supports the design of mobile tourism applications, but there are no general guidelines for future developments yet. Compared with the general research on mobile applications, the investigation of mobile tourism applications is limited. They are often based on case studies with small sample sizes. Few investigations have been done on investigating pedagogical approaches, which affect tourism experience and learning.

The usage of mobile tourism applications for exploring and gaining knowledge is not common yet. Due to this fact, the crucial motivational variables that will affect their adoption by users still need to be explored. This includes finding strategies to gain the visitors attention in urban space and adapting educational and motivational approaches from real-life city tours into the mobile augmented tourism application. Reviewing recent research works and existing applications will help to understand tourist desires and the complex concept of tourism applications, which have to combine educational purposes and entertainment in the future.

6 Further Research

These implications lead to further questions and their realization in the future. Our research aims to generate a prototype of an augmented four-dimensional city model implementing additional user interaction. In this respect, several challenges need to be addressed. From a technical perspective, the quality of automatically generated historical models is still not sufficient for an Augmented Reality application. Though the localization of historical images works semi-automatically in our prototype, we want to generate a fully automatic tool in the future, incorporating the findings presented in this paper. Following, a generation of models with higher quality should be possible. With these building models and additional images and metadata, we want to test different Augmented Reality scenarios concerning interaction and usability of such tools. Also, suitable presentations of the data and the observation of several data types will be part of future research.

We also want to do research on how to get the attention of potential users in urban space and how mobile AR applications can benefit from gamification approaches. Additionally, the enhancement of the user's experience with varying pedagogical approaches will play an important role. Thus, we want to combine an educational purpose with entertainment, leading to studies on feasibility, utility, practicability of applications concerning demands of different user groups.

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