Façade Map - Continuous Interaction with Media Façades Using Cartographic Map Projections

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ABSTRACT

The increasing number of media façades is a prominent example of the digital augmentation of urban spaces. Many media façades cover most of the outer shell of a building and come with a 3D form factor. They offer great potential for remote interaction in which the interactive area goes beyond the parts of the façade that are visible from the user's current perspective. Common interaction techniques often focus on a fixed part of the media façade. This restricts exploiting the full capabilities and the potential of such gigantic screens. In this paper we describe how to apply cartographic map projections to create 2D map representations of media façades to address this problem. We describe how a continuous interaction with the media façade is possible, independent of the form factor. We analyze existing media façades and provide a set of guidelines for how to create façade maps for different form factors.

Author Keywords

Media façade, interaction, mobile device, map projection, world in miniature.

ACM Classification Keywords

H.5.2 Information interfaces and presentation: User Interfaces - Input devices and strategies, Interaction styles, Graphical user interfaces.

General Terms

Design, Human Factors.

INTRODUCTION

As described by Seitinger et al. [22] and Bouchard [6], digital systems rapidly find their way into urban public spaces. An increasing number of large scale digital displays and *media façades* are embedded into the urban landscape. In contrast to situated public displays and displays or video walls that have a regular form factor and are attached to a building, media façades take the proportions and the architecture of the building into account. The term media façade describes the idea of turning the façade of a building into a huge public screen by extending its outer shell with interactive, light emitting elements [7, 21, 14]. The display might appear as a second skin of the building.

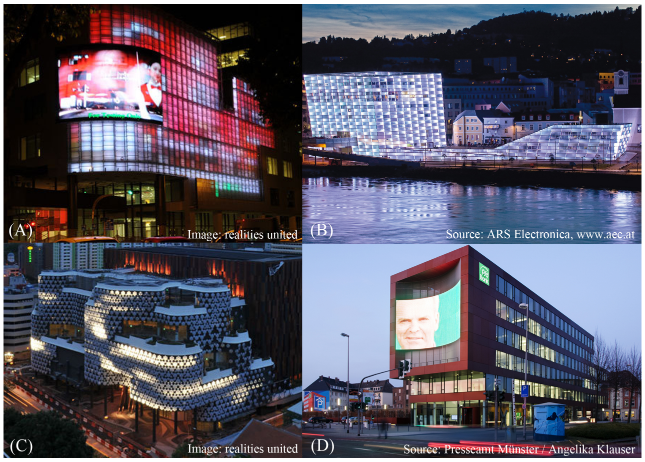

Image: realities united
Source: ARS Electronica, www.aec.at
Image: realities united
Source: Presseamt Münster / Angelika Klauser

Figure 1. Media façades of different sizes and form factors: (A) The A.AMP building in Singapore, (B) the ARS Electronica Center in Linz, Austria, (C) the Iluma Building in Singapore and (D) the PSD bank in Münster, Germany.

In contrast to situated public displays [19], media façades are very large in size. Their sizes vary from small media façades of about 50m^2 to very large ones like the ARS Electronica Center[1] in Linz, Austria covering about 5000m^2. Hence, they are visible from great distances. In many cases, media façades continuously cover more than one side of a building's façade and in some cases also the roof, which gives the media façade a three-dimensional (3D), non planar form factor (see Figure 1). Due to their size and the therefore required viewing distance, media façades are generally not within the reach of the users so that interacting with the media façade by direct touch input is not possible. If the façade is designed to be interactive, interaction from a distance is implied using a suitable interaction technique. Hence, common interaction techniques that are applied range from custom stationary input systems, e.g. for the Dexia Tower [16] in Brussles, Belgium over custom-made, individual input devices [11], to using regular smartphones for interacting with

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[1] http://www.aec.at

a media façade at a distance [4, 2]. In this paper we focus on interaction with media façades with regular smartphones as input devices, since this does not involve custom-made input devices and it represents the most generalizable interaction scenario.

Dalsgaard et al. identified eight challenges for designing urban media façades [8]. They state that media façades need to be integrated into physical structures and surroundings. This often leads to media façades that cover more than one side of a building. In this case, a potential user can only see the small part of the façade that is visible from his point of view. Parts of the façade might be occluded although the whole media façade offers a potentially interactive area. Existing applications for media façades that do not utilize stationary input systems mainly focus on the visible part of the façade. To exploit the full potential and the capabilities of media façades with a 3D form factor, the ultimate goal is to allow a fluent, continuous interaction with the whole media façade. If the user is supposed to have the possibility to continuously interact with the whole media façade through a regular smartphone, there is the need for an interaction technique that allows the user to view and access all parts of the façade, including the parts that are not visible from within the current point of view of the user. As one possible way to make the whole media façade accessible for user input, we propose to make all parts of the façade visible to the user – as on a cartographic map – on his smartphone and make them accessible by allowing direct touch input on the visualization. In [23], Skupin describes cartographic perspectives on information visualization. He discusses how geographic and cartographic approaches can influence the design of visualizations for textual information spaces. The use of map projections and map design are two ideas that we want to pick up to create a 2D representation of a media façade with a 3D form factor, similar to a geographical map.

In this paper, we describe how to apply cartographic map projections to create 2D map representations of media façades with arbitrary form factors. We provide insights on how such map representations can be used to realize continuous interaction with media façades. This includes interacting *over-the-edge*, where the user's focus of interaction moves from within the currently visible area of the façade to the occluded parts, and directly interacting with parts of the façade that are out of sight from a user's current point of view. As a use case for interacting with a media façade, we chose a painting application that alows the user to freely paint on the façade by touch input on the created map representation of the media façade directly on a smartphone. We consider this a suitable scenario to demonstrate the capabilities of our approach since with painting, we have direct visual feedback on the user's input. Furthermore, deformations and distortions that might be introduced by a mapping approach become directly visible while interacting and there is no need for the user to focus on any content, so he can focus on the interaction itself.

The remainder of the paper is structured as follows: First, we give an overview of existing related work, which is followed by the introduction of how to apply map projection techniques to allow a continuous interaction with media façades with various form factors. After that, we give an insight into the prototypical implementation of the system, before reporting on initial user feedback on the introduced interaction and visualization techniques. We conclude by discussing how the proposed concepts can be applied in a multitude of scenarios, followed by an outlook on future work.

RELATED WORK

Besides interaction with media façades, we identified two further areas that are related to our work, namely (1) 2D mappings of 3D surfaces and objects, as well as (2) interaction with the help of world-in-miniature representations. To follow, we give an overview on relevant work from these areas and we reveal how this is related to our approach. An introduction on different map projections, their application, and details on how they work will be given afterwards.

Media Façades

Designing interaction for media façades has been a recently emerging topic. Fischer et al. investigated spatial aspects in the design of shared encounters for media façades. They introduce the notion of Urban HCI, which emphasizes situations that are composed of the built environment, the interface and any associated computer system, and the social context [9]. In [4], Boring et al. describe a way to apply Touch Projector [3] to allow multiple users to simultaneously interact with a media façade – in their case the ARS Electronica Center – through live video on mobile devices. They segmented the overall media façade by defining two rectangular interactive areas (corresponding to the particular sides of the building) which were used as separate, independent interactive areas fully within the field of view of users standing in front of them. Introducing *MobiSpray*, Scheible et al. utilize a smartphone as a virtual spray can [20]. They use a world-in-miniature interface in combination with a large-scale projected media façade to allow spraying virtual color on various surfaces. In [1], Baur et al. use smartphones to apply the metaphor of optical projection to post visual content onto various digital surfaces in public multi display environments. With spread.gun [10], Fischer et al. built a stylized stationary cannon for shooting color dabs onto a projected media façade. In [11], Fischer et al. adapted this approach by exchanging the stationary input device for a mobile slingshot to support social interaction between users, since they have to pass around the input device.

The aforementioned approaches mostly require a direct line of sight between the user and the target area on media façade. In the case of mobiSpray, they require a user to navigate through a miniature representation of the environment to select the particular part of the façade. This restricts the interaction to a limited part of the potentially interactive area and hence might reduce the quality of interaction.

2D Projections of 3D Surfaces

Creating 2D representations of 3D objects is a well known concept in the areas of cartography and 3D modelling. In cartography, map projections are applied to create the 2D cartographic maps that we all know well and use on a regular basis for navigation or orientation. In 3D modelling, projections are applied to unwrap the surface of an object to a 2D image.

Cartography

In general, map projections concern the field of mathematical cartography. Map projcetions denote methods for mapping the dimensions, the shape and the features of the earth onto a 2D surface, a map. In [27], Tyner introduces the principles of designing maps. She gives a general introduction on how to create different maps for various purposes and she describes which map projections are most suitable to create the particular maps. Lev et al. focus on the theory of map projections [17]. They describe a wide range of map projection algorithms and how to apply them to create maps for various purposes. In [13], Greenhood describes basic theory about maps. He gives an overview on how to orient on a map and how to read maps to get a variety of information out of them. He introduces the concepts of different coordinate systems, scale, direction and topography. In [24], Snyder reviews the evolution from the early beginnings of historical maps to currently used map projections. We describe common map projections in detail when we introduce how to apply cartographic map projections to create 2D façade maps.

Texturing of 3D Objects

In the field of 3D modelling, creating 2D representations of 3D objects plays an important role for *texturing* 3D objects. The term texturing denotes the process of covering the surface of the 3D object with 2D images that are called textures. In [15], Heckbert defines a texture as *a detailed pattern that is repeated many times to tile the plane, or more generally, a multidimensional image that is mapped to a multidimensional space*. He surveys the fundamentals of texture mapping, including the geometric mapping that warps a texture onto a surface. The texturing of 3D objects generally follows two approaches: (1) A mapping of a 2D image onto the surface of the 3D object is created by distorting, scaling, rotating and moving the texture image or multiple copies of it until it covers the surface of the 3D object. (2) The surface of the 3D object is unwrapped onto a 2D plane which can be considered as a reverse mapping. The unwrapping is achieved by projecting the 3D object on a 2D plane with the help of different map projection algorithms in combination with a simple unfolding of the 3D object's surface. This can be compared to unfolding of a paperboard box. Both approaches have in common that the textures are generally distorted when mapping them onto or unwrapping them from the surface of a 3D object. In [18], Maillot et al. describe an approach to map textures with reduced distortion of the image. They constructed an interactive texture tool to manipulate atlases in texture space. They further introduced an algorithm which automatically generates an atlas for various types of objects, to map different textures onto the particular objects. We do not consider this approach for our purposes since it addresses the mapping of various – not necessarily coherent – texture images onto an object rather than on creating a 2D representation of an object's surface.

The goal of our work is to combine approaches from both areas – map projection and texturing 3D objects – in order to create a 2D representation of a media façade. With this, we want to enable a continuous interaction with the whole façade, independent of the current point of view of the user.

Visualizing complex content on small screens

When interacting with large contents like cartographic maps, web pages or 3D environments, the target area a person currently intends to interact with often covers only a small excerpt of the potential interactive content. Visualizing the whole content would therefore result in a waste of screen real estate. Common approaches to ease this problem are providing miniature representations or excerpts of the content. When dealing with geospatial content, a well known approach is to provide relevant excerpts of a map as orientation and navigation hints to the user. When interacting with 3D content or 3D environments, so-called world in minitaure representations are often utlized. Stoakley et al. introduced the *World in Miniature* (WIM) metaphor [26]. They use a miniature copy of a virtual environment to create a second dynamic viewport onto a virtual environment in addition to the first-person perspective that is offered by a virtual reality system. The miniature copy is a scaled-down representation of the environment that can be manipulated in a single level of scale. This complicates the task of navigation through the WIM. In [29], Wingrave et al. addressed the problem of navigating and moving around in a WIM by adding scaling and scrolling to the WIM metaphor, which resulted in a *Scaled Scrolling World In Miniature* (SSWIM). However, since the WIM representation keeps the 3D form factor of a media façade in the miniature representation, such an approach is limited in its suitability for enabling continuous interaction with a media façade since – although virtually – the user still has to move around in the WIM in order to access different parts of the façade.

FAÇADE MAP

We propose to apply cartographic map projections to create 2D map representations of media façades with various form factors. The 2D map representation, which we will call *façade map* from now on can be displayed on mobile devices such that touch input on the map the media façade can be directly transferred to the real media façade. Our goal is to describe a set of rules for how to use a 2D map representation of a media façade to allow for a continuous interaction with all interactive areas, independent of the current point of view of the user. Furthermore, while interacting, we want to create a smooth transition when interacting *over-the-edge*,

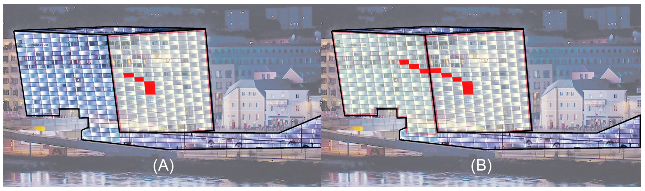

Figure 2. (A) Interaction limited to a fixed frame, here one side of the building. (B) Continuous interaction over-the-edge.

where the target area of the interaction continuously moves from within the current field of view of the user to adjacent areas outside the user's current field of view. This can be seen in Figure 2.

Map Projection

Map projections are methods from the area of cartography that are applied to convey the curved surface of a 3D Earth onto a 2D planar surface, a map. This is done with the help of a projection model. The formal definition of a map projection is *a systematic and orderly representation of the earth's grid upon a plane* [27]. Map projections are the mathematical mapping of the coordinates from the 3D to the 2D space, which corresponds to flattening the object. Applying map projections generally involves three steps:

1. Choosing a suitable projection model (sphere, cylinder, etc.).
2. Mapping of the geographical coordinates to Cartesian coordinates.
3. Scaling the map.

Most of the map projections are not projections in a physical sense. They are based on mathematical formulas. For a better understanding of how map projections work, we can think of a 3D object with a light source. The surface of the 3D source object is projected by the light source onto the surface of the projection model. Afterwards, the surface of the projection model is flattened by unwrapping it to a 2D surface (see Figure 3). A surface is called a *developable surface* if it can be flattened without distortion and without tearing the surface apart. Since not all 3D geometric shapes are developable, the choice of the projection model strongly depends on the properties that are intended for the later map. In general, there are an infinite number of projections possible, and more than 400 projections available, although only a few of them are employed regularly in practice [27]. In Figure 3, we can see characteristic map projections with different projection models. Since there is some overlap between the different available projections, a mutually exclusive classification is not possible. Hence, map projections are commonly classified based on (1) *preserved properties* and (2) the *projection surface*. As one effect of the circumstance that not every 3D shape can be flattened without introducing distortion, different map projections introduce different distortions and therefore preserve different geometric properties. Tyner categorizes the preserved properties as follows [27]:

- *Equivalence of area* (equal-area or equivalent projections). Stretchting in one dimension is matched by compression in the orthogonal direction to remain an equivalent area. In this approach, angles may be distorted, which leads to an altered shape.
- *Preservation of angles* (conformal projections). Angles are preserved with infinitely short sides. Hence, small areas retain the correct shape and for larger areas, the overall distortion increases. To be conformal, parallels and meridians must cross at right angles and the scale has to be equal in every direction from a point. Hence, stretching in one direction must be matched by stretching in the orthogonal direction. The most prominent conformal projection is the *Mercator* projection, which is the standard map projection for nautical purposes [12].

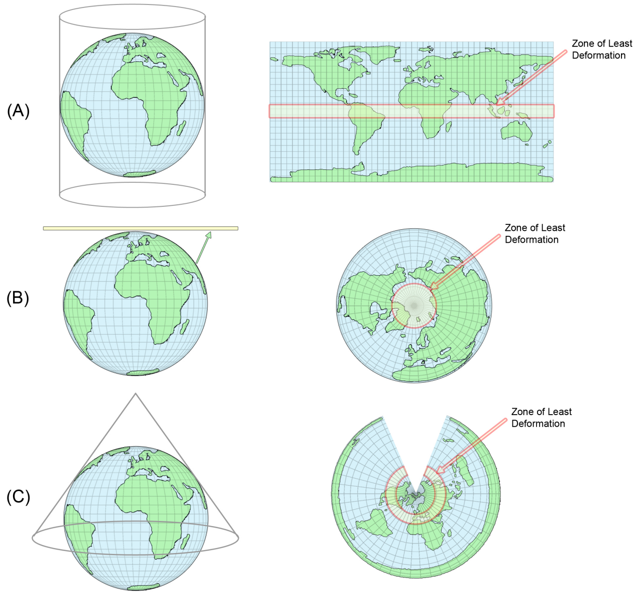

Figure 3. Characteristic map projections with different projection surfaces and the area of least deformation: (A) cylindrical projection, (B) azimuthal projection, (C) conic projection.

- *Linear scale* (equidistant projections). Distances are mapped correctly. An entire map cannot be equidistant, whereas the distance scale of a map is correct from particular points or along lines.
- *Directions* (azimuthal or zenithal projections). Azimuths are shown correctly and the directions from a central point are preserved. Azimuthal projections usually have radial symmetry in the scales and the distortions. Measuring the azimuth between any other points is not possible.

A second approach to categorize map projections is categorization according to the projection surface. For the sake of simplicity, we describe this through the example of creating a map of the Earth (see Figure 3). Common projection surfaces are:

- *Cylindrical*
  When using a cylinder as the projection model, the surface of the globe is projected onto the surface of the cylinder which is then flattened to obtain the map. On the obtained map, the latitude and longitude graticule of the globe results in a grid structure where the meridians of longitude are equally spread and the parallels of latitude remain parallel but are not equally spread. Due to the spherical nature of a globe, the least deformation for projecting a globe occurs around the equator. Cylindrical projections are well suited for spherical or curved objects. A prominent cylindrical projection is the Mercator projection.

- *Cubic*
  Cubic projections are not classical geographic map projections. Their main field of use is the *UV mapping* of texture images on 3D objects. UV mapping denotes the process of creating a 2D image representation of a 3D object in the process of 3D modelling. The 2D texture image is mapped with UV coordinates onto the surface of the 3D object. The textured surface of the 3D object is usually cut along a manually defined seam. This seam defines which connected parts of the texture remain connected and which will be cut. A cubic projection can be considered as flattening a cube by simply unfolding its surface like a box (see Figure 3). When projecting the surface of cuboid source objects, the area of least deformation is represented by the whole outer faces of the cube, which means that there is no deformation at all introduced.

- *Azimuthal* (Projection on a plane)
  With azimuthal projections, the surface of the globe is directly projected onto a plane. This projection has a radial symmetry in scales and distortions. Hence, azimuthal projections are well suited for mapping radial areas. The projection is constructed with a plane tangent to the globe, usually at one of the poles. The radial area around the osculation point is then mapped onto the plane. The deformation is minimal around the osculation point, and it increases with distance from it.

- *Conic*
  With conic projections, the surfaces of the source object are projected onto a surrounding cone which will be unfolded. Conic projections of a globe are created by putting a cone over the globe such that it is adjacent to a parallel. This parallel is called the *standard parallel of projection*. Around the parallel, the deformation is minimal; it increases with distance from the parallel. Conical projections are well suited for midlatitude areas on a globe and circular paths around an object.

For each of the described categories, there is a huge number of available adapted approaches, as well as approaches that address particular properties of visualization to optimize the created maps for such dedicated purposes as visualizing large areas like the Earth. Since our goal is to create map representations of relatively small areas of various shapes, we focus on the general algorithms. In summary, we can say there is a huge variety of map projections available. Since they offer different features and have different characteristics, choosing a projection strongly depends on (1) the surface of the object that is intended to be mapped and (2) the purpose of the obtained map. Due to their ability to preserve different geometric properties, map projections are also highly suitable for creating 2D map representations of the surface of arbitrary non-spherical 3D objects, like buildings that are equipped with media façades.

Map Representation of Media Façades

Due to the variety of map projections that are available and due to their differing characteristics in preserved geometric properties and introduced deformations, there is no general rule for choosing the right projection for creating a map of a media façade. If the media façade covers the whole outer shell of the underlying building, the building's whole surface needs to be mapped. If the media façade covers only parts of the building's surface, we can omit the parts that do not host media façade elements for the mapping. In this case, a map projection can be chosen that best fits the characteristic geometric properties of the media façade. Different projections work with differently shaped surfaces. Hence, the form factor of the media façade is one key aspect when choosing a projection. A second important aspect is the purpose for which the obtained map is intended.

Media façades are not necessarily rectangular or of a distinct shape. They are integrated into the structure of a building that serves as a host. This leads to various, irregular form factors. In many cases, e.g. the ARS Electronica Center[2] or the Kunsthaus Graz[3], the shape of the media façade includes different characteristic elements for which different map projection approaches are suitable. The map projection needs to be chosen according to the geometric properties which are to be preserved. Since the goal is to obtain a 2D map of the media façade's surface that enables users to intuitively orient themselves when interacting with the façade, the main shapes and the main layout of the media façade need to be preserved. In addition to shape and layout, when interacting over-the-edge (see Figure 2), the borders of the areas adjacent to the ones within the current field of view of the user should also be coherent and preserved in the map representation to enable a continuous flow of interaction.

We investigated permanent media façade installations that are listed in the literature [14, 5, 7, 25, 22, 16] and for which information is available throughout the web. The media façade installations are distributed around the globe. We compared their form factors, capabilities and geometrical properties to identify form factor categories that describe basic conditions which are relevant for map projections. For each category, we examined suitable map projections such that a feasible trade-off of basic shapes, the layout of the media façade and adjacent areas and edges are preserved to obtain a coherent map representation with minimal deformation. We derived the following dominant form factors of media façades, for which we provide a set of guidelines to derive a façade map, and for which examples are depicted in Figure 4:

Cubic

Cuboid form factors are the dominant form factors among existing media façade installations. This denotes rectangular media façade installations that face the outer shell of a building. When they cover more than one side of a building, their form creates a 3D shape that is similar to the outer surface of a cuboid. If the media façade spans around the outer shell of a building and has a cubic form factor, we have to distinguish two major cases: (1) The media façade is only formed by the outer shell (or a part of it) along the side of the building. This case can be compared to a cube without top and bottom. (2) The media façade is formed by the outer shell covering the building, including the roof. In both cases,

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[2] http://www.aec.at

[3] http://www.museum-joanneum.at/en/kunsthaus

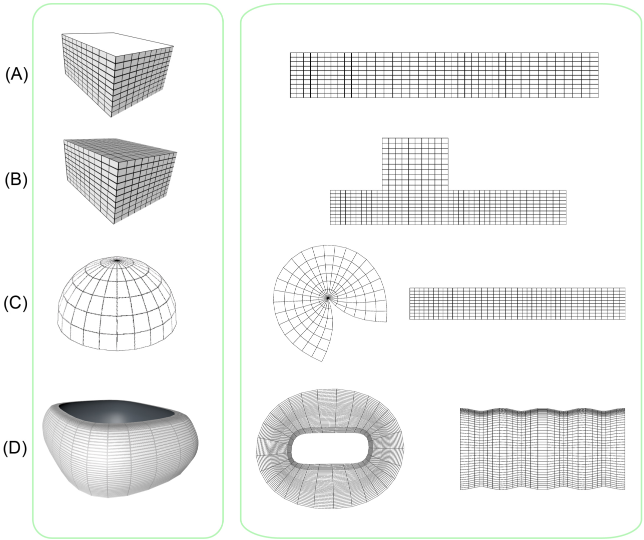

Figure 4. Map projections for different building shapes. (A),(B) Cubic form factor: cubic projection. (C) Spherical form factor: (left) conic projection, (right) cylindrical projection. (D) Curved form factor: (left) azimuthal, (right) cylindrical projection

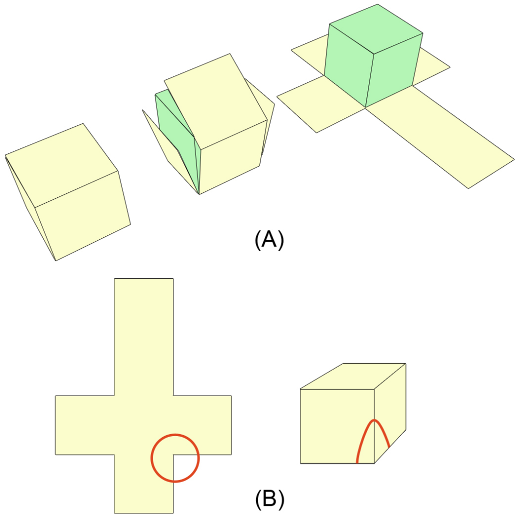

Figure 5. (A) Unfolding a cube. (B) Distortion introduced by interaction over unpreserved edges.

a well suited map projection to obtain a 2D map of the media façade's surface would a cubic projection, since for cuboid or rectangular shapes, there is no or only little deformation introduced by the projection. If the top of the building is not a part of the media façade (e.g., the Bayer Media Sculpture[4]), the map obtained by the cubic projection is already sufficient, since the particular areas, the layout and the borders are preserved (see Figure 4). The obtained map in this case also contains only one contiguous rectangular shape.

In the case that the top of the building is also part of the media façade (e.g., the National Aquatic Center[5] in Beijing, China), a cubic projection with a plain unfolding of the projection shape is not sufficient since when unfolding the cube, the top side is only connected to one side part of the cube. As a result, only this one border between the top and side parts of the façade is preserved. This leads to gaps between adjacent parts of the media façade in the obtained map. If we aim for a continuous interaction with all parts of the façade, this hinders the interaction, since when the focus of interaction moves from the side parts of the façade to the top part, a continuous transition is only possible from the side part for which the border to the top part is preserved on the 2D map. Interaction over unpreserved edges introduces a distortion in the flow of interaction. As depicted in Figure 5, this becomes clear when considering drawing on the façade by touch input on the 2D map. If we try to draw a circle around a corner where three sides meet, the contour of the circle overlaps with a part of the map that is not part of the media façade's surface. Since the unused parts are literally removed during the texturing, the circle that was drawn appears distorted in the direction of the border which was not preserved during mapping.

One possibility to counteract this problem could be to adjust the seam along which the surface is unwrapped to obtain the façade map, to create a *set of façade maps* where the different borders are preserved. Then, the façade map could be dynamically exchanged while interacting, such that when the user is interacting with a particular area, all borders to neighbouring areas are preserved. We believe that this might also be a drawback. Since the user directly interacts with the façade map, his interaction might be interrupted by changing the map and he might temporarily lose the orientation on the map. This remains an issue that needs further investigation. Since Wiethoff and Gehring found that when interacting with media façades, users often chose enjoyment over ease-of-use [28], we want to evaluate in the wild whether users perceive this as a problem.

Spherical

We denote media façade installations that are dominated by a spherical form like a dome (e.g., the media façade of the Grand Lisboa hotel[6] in Macau) as having a spherical form factor. For media façades with a spherical form factor, we propose to apply either a conic or a Mercator projection (see Figure 4), dependent on the purpose of the map. If people stand in front of a spherical media façade, they usually see the lower parts of the façade from a perspective that is close to orthogonal. They are the primary target areas for interaction. Moving further toward the roof of the dome, the visibility decreases for a user that is standing on the ground in front of the façade. Hence, the area of least deformation of the façade map should be around the lower parts of the façade.

For conic projections, the area of least deformation is around the standard parallel. Depending on the size and the degree of curvature of the media façade, the area of least deformation tends towards the lower parts of the façade. The obtained map has a radial layout and is therefore well suited for vertical interactions over the top of the sphere, since the coherent structure of the top of the sphere is visible on the

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[4] goo.gl/6pb6C

[5] http://www.water-cube.com/en/

[6] http://goo.gl/KKZtk

map. In contrast, a standard Mercator projection creates a rectangular map where the mapped content is oriented horizontally on the map. In this case, the area of least deformation is located around the equator of the sphere. Since spherical media façades usually are only half-spheres, the least deformation will occur in the lower parts of the façade. The rectangular layout of the map makes a standard Mercator projection well suited for horizontal interaction around the façade and less suited for interacting over the top, since the coherent structure of the top is not preserved by the map. If we want to create a map that preserves the coherent structure of the top of the sphere and that is therefore suitable for interacting over the top of the sphere, we could use a *traverse* Mercator projection. This is an adaption of the standard Mercator projection with a horizontal projection axis, whereas the standard Mercator projection has a vertical projection axis. The mapped content in this case is oriented vertically on the obtained map.
An azimuthal projection would not be suited for spherical media façade since for azimuthal projections, the area of least deformation is around the tangent point of the projection plane, which is generally the topmost point of the sphere. This would result in the area with the least visibility being the area of best presentation on the obtained map.

Curved

We denote the form factor of a media façade installation as curved if is dominated by spherical and elliptical shapes that do not form a sphere (e.g., the media façade of the Allianz Arena[7] in Munich, Germany or the iluma[8] building in Singapore, Malaysia). For media façades with a curved form factor, the choice of a suitable map projection depends on the degree of curvature of the media façade, as well as its placement on the outer shell of the hosting buildung. If the media façade forms an elliptical ring around the host building, as for example the media façade of the Allianz Arena, a conic map projection is a suitable approach. Since conic map projections have the area of best presentation around the standard parallel, the media façade can be mapped with low distortion if the projection cone is chosen such that the standard parallel lies within the area of the media façade. If the curved shape of the media façade is rather flat, an azimuthal map projection would also be suitable to create a map. In this case, the façade is depicted as a coherent structure. For more complex curved shapes, we suggest applying a cylindrical map projection. The area of best presentation is located around the center line in the case that a sphere is mapped. If the mapped surface consists of several spherical shapes, the areas that are located around the horizontal center line of the particular shapes are mapped with the least distortion.

For media façades where the form factor is dominated either by cubic, spherical or curved shapes, a map representation of the façade's surface can be obtained as described. If the form factor is dominated by shapes of more than one of these categories, there is a trade off among properties that are relevant for the intended interaction and that therefore have to be preserved. One possibility could be to create a map with different map projection approaches that work best with the particular category, for each affected category, and switch during the interaction.

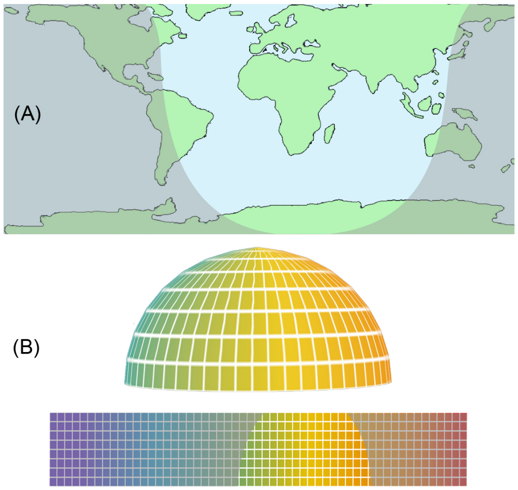

Figure 6. (A) A daylight map visualizing the current day and night zones. (B) The daylight map metaphor applied to a façade map to visualize the currently visible area.

With a façade map, a user can interact with all parts of the media façade. This also includes the parts of the façade that are occluded from the user's current point of view. To assist the user in orienting himself on the façade map, we propose to apply the metaphor of a *daylight map* to the façade map. Similar to visualizing the current area of daylight on a map of the world by displaying a shaded overlay image over the area of night, we propose to display a shaded overlay image over the façade map to slightly shade the areas of the media façade that are occluded from the user's current point of view (see Figure 6). As soon as the user changes his current location or orientation, the field of view and hence the visual parts of the façade change as well. In this case, the overlay is dynamically adjusted to the current field of view of the user. To determine the location of the user and his orientation towards the media façade, we can utilize the built-in GPS and accelerometer sensors as well as the built-in compass of the user's mobile phone through which he interacts with the façade. Hence, we can consider them to be available. Knowing the location of the media façade and the geometric conditions from creating the façade map, we can dynamically estimate the current field of view of the user and automatically adjust the overlay on the façade map.

Combining the introduced concepts of map projection and texturing with the proposed guidelines for creating map representations of media façades of various form factors, the presented work creates a framework that enables new ways of continous interaction with all parts of a media façade. This is further step towards the exploitation of the full capabilities of media façades as urban displays and digital mediums.

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[7] http://goo.gl/wVsXe
[8] http://www.iluma.com.sg

IMPLEMENTATION

To support the development of the proposed guidelines for creating façade maps with map projection approaches and to gain early feedback on interaction with the maps, we developed façade map prototypes and interactive 3D media façade models for the described form factors and map projections. We used the 3D modelling software Blender[9] to create 3D models of media façades with characteristic cubic, spherical and curved form factors. Since Blender offers the possibility of adding custom functionality by importing Python scripts, we implemented standard map projection algorithms in Python and applied them to the 3D model within Blender to project the surface of the 3D model onto a 2D texture image. We created a UV mapping to rebind the 2D texture onto the model. To gain a realistic impression of the interaction, we implemented a client-server application for interacting with a 3D model of the façade while using a mobile phone as the input device. As a use case, we chose a painting application where the user can freely paint on the façade. A façade map is displayed on a mobile phone and the user can paint on the 3D model of the façade, by painting on the façade map on the mobile phone by direct touch input. We used the jMonkey[10] engine for openGL to write a server application in Java that displays the respective textured 3D model of the media façade. The client application for the smartphone was written for the Android platform. The application displays the façade map and offers the possibility of painting freely on the façade with different colors and brushes. Client and server applications communicate over a wireless network connection. The client application on the mobile phone sends the necessary data, like the input events, to the server application, which maps the user's input from the 2D space of the mobile phone into the 3D space of the façade model. The application was designed to support importing new 3D models with the respective façade maps to experiment with various form factors.

USER FEEDBACK

In [28], Wiethoff and Gehring describe the importance of getting early feedback when designing interaction for media façades and incorporating the feedback in the ongoing design process. Following their approach, we utilized our prototype implementation to gather initial informal feedback on general usability and the user experience when interacting with façade maps throughout the individual stages of the overall design process. During the development of the map projections for different form factors, we let our prototype for displaying the 3D model of the media façade run on a standard desktop computer, and utilized Android-based tablet computers and mobile phones on which the façade map was displayed for interacting with the 3D model. We asked colleagues and students that visited our lab to play around with the prototype. Before they started interacting for the first time, we only told them that they could choose a color and a brush size and that they should paint on the façade of the 3D model by painting on the façade map displayed on the mobile device with their fingers, by touch input. Afterwards, we discussed with them in unstructured interviews what they thought was good and bad about the general approach and the particular maps that they used. We asked about how easy it was to orient themselves on the façade map as well as how they experienced the drawing (e.g., did distortion occur or not). We incorporated this initial feedback in the further design process to refine the set of map projections that we proposed.

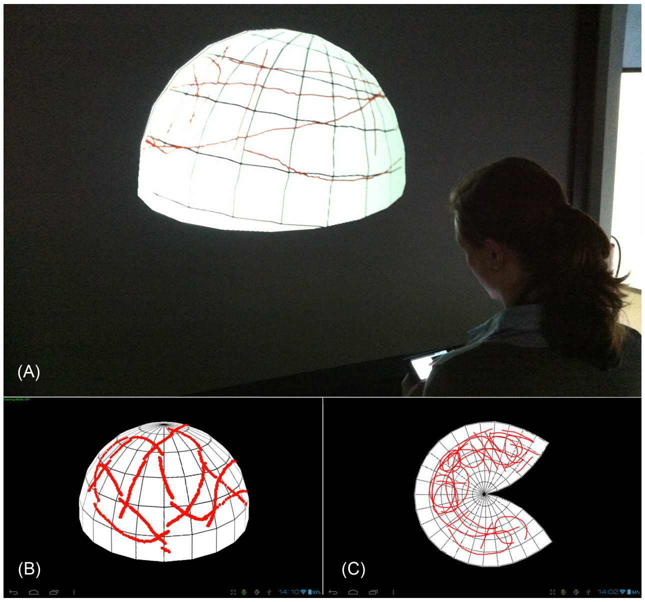

Figure 7. (A) A participant interacting with the 3D model of the media façade on the projection wall. (B) The client application, showing a world-in-miniature model of the façade. (C) The client application, showing the façade map.

For our final set of map projections, we gathered further user feedback. We asked 10 people, which own a smartphone and are familiar with using it, to paint on the 3D models of media façades with the façade map prototype. The 3D model of the façade was displayed on a $15m^2$ projection wall, and the client application showing the façade map was running on a mobile device (see Figure 7). All participants interacted with all media façade - map projection pairs, which are depicted in Figure 4. We further applied the world-in-miniature metaphor such that every participant additionally had to perform the painting task directly on a miniature representation of the façade's 3D model, which was displayed on the mobile device. Afterwards, we asked the participants in unstructured interviews about the design and usability of our prototype as well as their experiences using it. We focused our questions in particular on the map layouts and therewith connected issues like orienting themselves on the map and the deformation of the displayed content, as well as the connection between enjoyment and ease of use when using the prototype.

The participants in general chose the façade maps over the world-in-miniature representation of the media façade as the prefered interaction technique. As common reasons for their choice, they stated that in contrast to the world-in-miniature representation, the façade map does not involve scaling and scrolling while trying to paint and they found it easier to continuously paint lines around the façade on the map. In

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[9] http://www.blender.org

[10] http://jmonkeyengine.com/

this context, the participants also positively mentioned the façade map helped them to get an impression on the overall content of the façade. Concerning orienting themselves on the façade map, the participants appreciated the visualization of their current field of view, by applying the metaphor of daylight maps to the façade map. When having a map, where parts of the façade are displayed upside down, some participants also suggested to automatically rotate the map in relation to the current focus of interaction to make sure that the current target area is always aligned horizontally. Furthermore, they demanded for the functionality of manually switching between different map projections. In terms of the deformation of the content when painting over unpreserved edges, the majority of the participants did not consider this as an disturbing issue. In summary, we can say that the feedback was throughout positive.

DISCUSSION

We proposed to apply map projections to the surface of media façade installations to create 2D façade maps and to utilize them to enable continuous interaction with the whole façade. Although we restricted the described use case to painting on the façade – which is a rather limited interaction – the façade map approach is thoroughly generalizable as an input technique to make the surface of a media façade accessible by direct touch. In contrast to visual interaction techniques as described in [4], façade map does not rely on shifting light and weather conditions, which are mentioned as challenge number 3 – *Increased demands for robustness and stability* – of the eight challenges for urban media façade design descirbed by Dalsgaard et al. [8]. Furthermore, with the façade map approach, a continuous interaction with the media façade is possible, where even those parts that are not within the current field of view of the user or which are currently occluded are still accessible.

In addition to serving as a means for input, a façade map could also be used as a visualization technique. Since the whole media façade is depicted on the map, it would also be possible to display the current content of the media façade on the façade map on the mobile device of the particuar user. As a result, a user could easily gain an overall impression of the displayed content and, in the case of painting for example, unused spots on the façade could easily be identified. If the current position of the users can be determined relative to the media façade, façade map can also serve for visualizing the current locations of the different users. This can enhance the user experience when multiple users are interacting with the media façade at the same time, since as described in [4], not knowing who else is interacting at the same time is a circumstance that is often mentioned as a cause of frustration.

We do not attempt to provide an extensive framework, since there might occur further permanent media façade installations with different form factors for which the proposed guidelines are not fully applicable to create a suitable 2D façade map. In further research, we want to apply façade map to various media façades with different, unusual form factors to further refine and extend our approach.

CONCLUSION & FUTURE WORK

In this paper we transferred the concepts of cartographic map projections that are used to create 2D maps to the field of media façades. We described how to use façade maps on a mobile phone to interact with a media façade. Furthermore, we showed how using façade maps can help to take a further step towards exploiting the full capabilities of media façades of various form factors by enabling a continuous interaction with all parts – even the parts that are occluded – of the façade, independent of the user's current field of view. We analyzed the form factors and geometric properties of available permanent media façade installations and identified their dominant shapes. For each category, we provided guidelines for creating façade maps and proposed suitable map projection approaches. We implemented prototypes for interacting with realistic 3D models of façades with various form factors by using façade maps on a mobile phone. We gathered initial user feedback during the individual stages of development about the general usability of façade maps as well as on emotional aspects of the interaction. The feedback confirmed that the presented work is a valuable step towards making use of the full capabilities of media façades and establishing them as an urban hub of interaction.

In future work, we plan to apply façade maps in a multitude of real world settings for media façades with different sizes, form factors and capabilities. We want to address the problem of gaps that can occur in a map if some coherent edges are not preserved by the projection, as occurred in the case of media façades with a cuboid form factor if the top side of the spanned cuboid is also a part of the media façade. We want to investigate, to what extended the user can be guided over disrupted areas, when drawing coherent lines. In addition, we want to investigate the combination of map projections and the use of mixed projections to obtain better maps. Within this scope, we want to build on the presented work and investigate how to put a dynamic focus layer, like a lens, on top of the static map to dynamically adjust the map projection. Thus, we want to dynamically chose the best suitable map projection for the current focus area. Furthermore, we want to expand our prototype implementation to a general tool with which designers can import a 3D model of a media façade to create their own façade maps. Within this scope, we want to develop algorithms to automatically determine the best mapping given a particular building and façade.

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