GPS Lens - GPS Based Controlling of Pointers on Large-Scale Urban Displays Using Mobile Devices

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ABSTRACT

The increasing number of media façades in urban spaces offers great potential for interaction. Due to their size and physical properties interacting with them directly by touching them is not possible. In this paper, we present a sensor-based approach, which relies on the GPS, compass and accelerometer data of a mobile device to control a pointer on large-scale urban displays, such as media façades. We calculate the pointing direction based on the location and orientation of the mobile device and display a preview of the content around the current cursor position to overcome the limitations of current GPS sensors. We further report on an initial user evaluation, revealing the presented approach as accurate and easy-to-use.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces - Input devices and strategies, Interaction styles, Graphical user interfaces

General Terms

Human Factors

Keywords

Mobile device, media façades, interaction techniques, input device

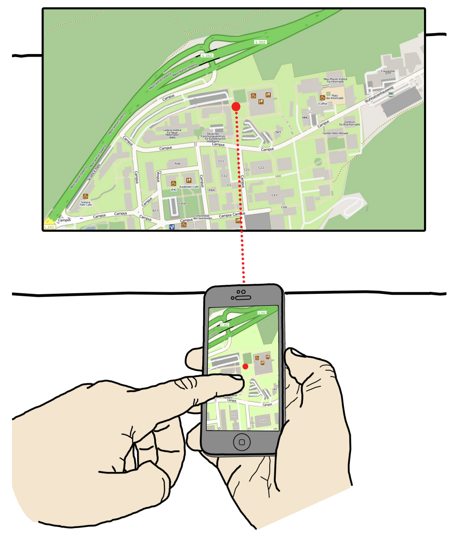

Figure 1: Pointing at a display with a mobile device. The content around the current pointer position on the display is displayed as a preview on the mobile device's screen, with which the user can interact by direct touch input. The current pointer position (red dot) is displayed on both the mobile device and the remote display.

1. INTRODUCTION

Large-scale urban displays and so-called media façades are prominent examples of the rapidly increasing augmentation of public places with digital technologies [8, 21]. The Beijing National Aquatics Center in Beijing, China and the ARS Electronica center in Linz, Austria are just two prominent examples out of hundreds of such façades. 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 [13, 20, 16]. Hence, the display might appear as the skin of the building. In contrast to situated public displays, media façades are therefore very large in size. E.g., the media façade of the ARS Electronica Center covers about $5000m^2$. Hence, interacting with them directly, by touching them, is usually not possible. Recent works have introduced interaction techniques, allowing users to interact at-a-distance with large-scale urban displays and media façades using mobile devices [6, 11]. However, utilizing them requires certain efforts. They are usually tailored to one specific façade and cannot be transferred to other settings without further ado, or in case of [6], they rely on visual data, making them dependent on changing weather and lighting conditions. Since media façades usually are large in size and enclosed by open spaces or plazas, using GPS could open ways to provide interaction techniques for media façades that could be adapted to new settings with ease.

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In this paper, we present GPS Lens, a lightweight interaction technique to control pointers on large-scale urban displays with mobile devices (see Figure 1). Our approach utilizes the built-in GPS sensor, compass and accelerometer of the mobile device to compute the pointing direction of the user. To overcome the limitations of current GPS sensors, we adapt the Magic Lens metaphor [4] and display a preview of the display's content around the current pointer position on the local screen of the mobile device. With this, we provide a detail view on the mobile device's screen for the area of interest on the remote display. To overcome the inaccuracy of the current pointer position introduced by inaccuracies of the GPS signal, users can interact with the remote display's content through the detail view on the mobile device with the high precision of direct touch input. Furthermore, we report on the results of an initial user test, which revealed our approach as accurate and easy-to-use.

2. RELATED WORK

Urban Spaces are recently emerging as prime locations for the deployment of digital technologies, such as media façades [21]. The term "media façade" generally refers to the idea of turning the surface of buildings into giant public screens [13, 24]. To achieve this, the outer surface of the building is equipped with digital, light emitting elements. Due to their size and since situated in a highly dynamic public context, designing interactive systems for media façades introduced new challenges. Dalsgaard et al. describe eight key challenges that have to be faced when developing such novel interactive systems and when providing new interfaces [9]. Existing interfaces and techniques need to be adapted to new settings and due to the dynamic nature of urban settings, there is an increased demand for stability and robustness.

In recent work, researchers have proposed several techniques to interact with large-scale urban displays at-a-distance. Prominent techniques are augmented reality, as well as pointing approaches. In [5], Boring et al. introduced TouchProjector, an augmented reality approach, which allows interacting with a distant situated display showing in the viewfinder of a mobile device using touch in real-time. In [6], Boring et al. adapted TouchProjector to allow multiple users to simultaneously interact with a media façade in a public setting. Ballagas et al. proposed an approach for relative and indirect pointing by turning a camera-equipped mobile phone into a mouse-like device [1]. Similar to this, Boring et al. presented a camera-based approach to continuously control pointers on remote display [7]. However, these approaches are heavily influenced by environmental conditions, such as weather or light conditions. Furthermore, they require the user to be either within a distance where the whole display is visible in the current camera field or within a very short distance, such that the camera of the mobile device can capture the content of the display in sufficient detail. With MobiSpray, Scheible et al. provided a world-in-miniature interface for virtually spraying color on projected surfaces, utilizing the accelerometer of a mobile device [19]. MobiSpray is therefore tailored to a specific place and it requires a certain effort to set it up. Fischer et al. introduced SMSlingshot [10], a playful installation, where users can shoot custom messages onto a projected media façade by pointing and shooting with a custom-build input device, looking like a common slingshot. The target position is determined by tracking a laser, which is activated when pulling the slingshot for aiming. This approach therefore requires a rather complex setup. Vogel and Balskrishnan explore the design space of freehand pointing and clicking with very high-resolution displays from a distance [25]. They provide and evaluate three techniques for gestural pointing, as well as two for clicking. However, the provided techniques require a tremendous instrumentation of the area in front of the display. In [18], Olsen and Nielsen describe how to track the position of laser pointers with cameras as a possibility to interact with remote displays. They provide calibration techniques to synchronize the display and camera coordinates.

For pointing at remote displays, Myers et al. investigated the performance of different pointing devices (e.g., laser pointer, PDA, gun) for different pointing postures [17]. They investigated seven different ways to hold various kinds of laser pointers. They found that tapping on a wall-sized display is the fastest and most accurate method, followed by copying an area of interest from the remote display to a handheld device. Since proven to be fast and accurate for pointing tasks on remote displays, we decided to build our work upon this approach. In [17], Myers at al. studied an indoor setup, where a laser pointer was mounted onto a PDA. The position of the laser pointer was tracked by a camera system. We adapt this approach for outdoor use, utilizing only GPS, accelerometer and compass data provided by the mobile device's built-in sensors. Our approach does not rely on any further tracking.

In [2], Baus et al. incorporated pointing devices into real world settings. They present ARREAL, an augmented reality outdoor navigation system, where users can use a modified electronic compass as a 3D pointing device to point at buildings in order to get additional information. However, the described system requires a certain instrumentation of the user, as well as information about the environment itself. Simon and Fröhlich introduced a framework to develop mobile geospatial web applications [22], allowing users to point with a mobile device to perform spatial queries based on visibility and field of view. The queries return information on points of interest (POIs) withing this direction. Similarly, Lei and Coulton presented the gesture controlled Geo-wand [14]. Users can point with a common smarthpone at directions to get information in POIs. In addition, they can add information such as photos to the POIs. Both systems provide information on the set of POIs in a certain area. In contrast, Beer describes GeoPointer [3], a system detecting a particular building a user is pointing at with a mobile device. We want to pickup these ideas to utilize GPS for controlling virtual pointers on urban screens.

In order to be independent from changes in environmental conditions like lighting conditions and to provide a light weight, low bandwidth demanding technique to control a pointer of large-scale urban displays, such as media façades, we decided to utilize the built-in GPS sensor, accelerometer and compass of a mobile device.

3. GPS LENS

The goal of our work is to utilize the mobile device of a user as a pointing device to control a pointer on a media façade. The pointer movement is calculated based on data

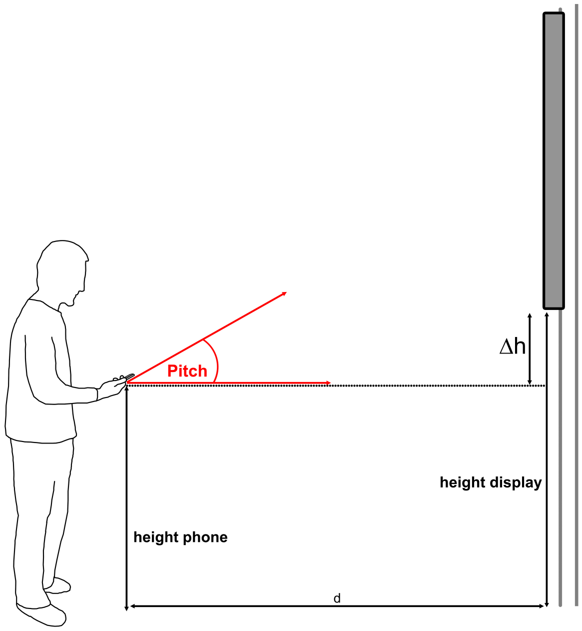

Figure 2: Calculating the vertical intersection of the current pointing direction and the vertical display area.

obtained from the GPS sensor, accelerometer and compass of the mobile device. To point with the mobile device, we decided for a posture as described in Figure 2, where the user is holding the mobile device in front of his body, in a height that is comfortable for reading the content of the mobile device's display. We consider this to be the optimal posture since the user needs to be able (1) to point with the mobile device at the display and (2) to see the content displayed on the mobile device's screen and to be able to interact with it at the same time. Since GPS only provides ground truth data, we incorporate the height of the phone into the calculations.

3.1 Calculating the cursor Position

To control a pointer on a large-scale urban display such as a media façade based on GPS data, we need (1) the current location of the mobile device, as well as (2) the GPS coordinates of the media façade's boundaries. To map the pointer onto the façade, in addition to the GPS coordinates of the left and right boundaries, we also need information about the exact height of the media façade. The accuracy of the altitude, measured by low cost GPS receivers is specified by the manufacturers to be +/- 15m in 95% of the measurements. However, utilizing digital elevation models (DEM) [15] to get the altitude of the current user location could easily circumvent this inaccuracy. Using the measured altitude for calculating the pointer position would introduce an error, which may make the system unusable. When interacting with a media façade by pointing at it, we can assume that the user is standing in front of the actual media façade. For the sake of simplicity, we assume that the area in front of the façade is flat and we can calculate a relative difference in altitude between mobile device and façade. If there was a significant pitch in the area in front of the façade, the difference in altitude could be easily measured in advance

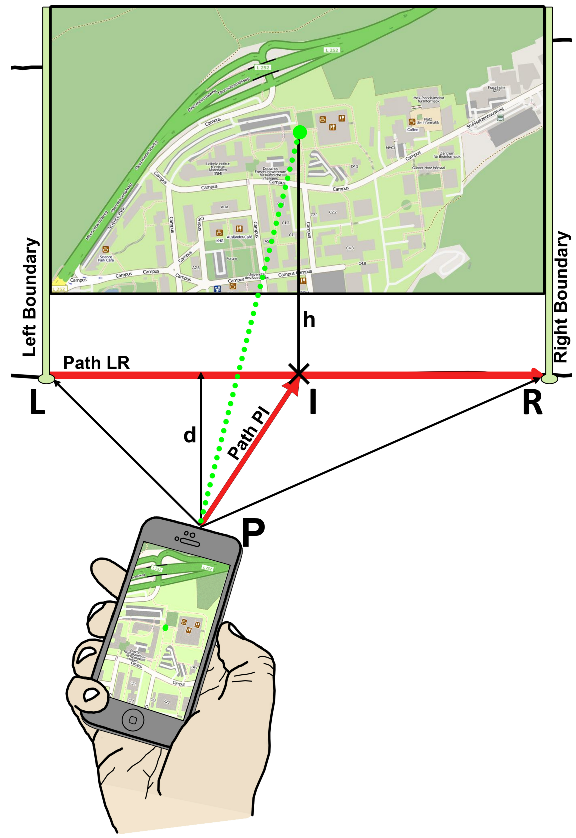

Figure 3: Calculating the horizontal intersection of the current pointing direction PI and the display area.

and mapped to the relative position of the user. In terms of horizontal accuracy, although common smartphones state an accuracy of 5m as a higher boundary, our measurements showed that the actual accuracy often still is better. For optimal conditions, we measured an average accuracy of 1-2m for an iPhone5, compared to dedicated GPS sensors. Since we can assume that a user stands relatively close to the media façade while interacting — at most a few hundred meters — we can apply abbreviations when computing the pointing direction and we do not have to incorporate the curvature of the earth in our calculations.

All formulas applied in our calculations are standard formulas to calculate geographical relations between latitude-longitude points [12, 23]. Due to the limited space, we leave out a detailed description of the formulas. As depicted in Figure 3, the pointing direction is calculated as follows: The user is pointing at the display if the pointing direction of the mobile device in the user's hand intersects with the media façade's boundaries both horizontally and vertically. In the description of the calculations, since calculating with short distances of several meters, we can use the term heading to describe directions and orientations. There is no need to distinguish between heading, which varies when following a great circle path, and bearing, which is also referred to as the forward azimuth. For sufficiently short distances, as in our case, both can be considered equal. To detect a horizontal intersection, we initially calculate the heading from

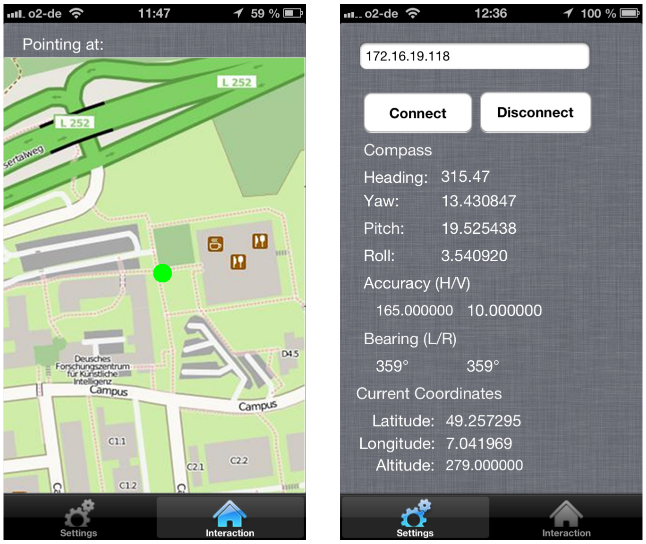

Figure 4: The interface of the mobile client prototype. Left: The detail view displaying the content around the current cursor position. Right: A settings view, displaying the current sensor data, utilized for calculating the cursor position.

the location (P) of the pointing device to the left (L) and right (R) display boundaries. Afterwards, the heading of the current pointing direction from P is calculated. If it is between the heading from P to L and P to R, the pointing ray casted by the mobile device intersects the area between the horizontal display boundaries. In general, the geographical intersection point I can be calculated as:

$$I = intersection(path(L, R), path(P, currentHeading))$$

The geographic coordinates of I can be calculated in three steps: (1) at first, we calculate the path between L and R, denoted as LR. (2) Second, we calculate the path from P in the direction the current heading of the mobile device, denoted as PI. (4) Finally, we can calculate the intersection point of both paths [23].
After detecting an intersection between the pointing ray and the horizontal boundaries of the façade, we need to check for an intersection with its vertical boundaries to make sure the pointer is within the visible area of the media façade (see Figure 2). In order to calculate the height of the vertical intersection in meters, we first calculate the distance d between the point P and the horizontal intersection point on the path LR. In the geographical context, this would mean to calculate the Haversine [12, 23] distance. Since we are dealing with a sufficiently short distance, we can use the less computation intensive Pythagoras theorem. Along meridians, the Pythagoras theorem does not introduce errors. Otherwise, the errors depend on distance, bearing and latitude. However, they are negligibly small for short distances. With the distance d, the current Pitch — measured with the built-in accelerometer — of the mobile device and the height difference between mobile device and lower display boundaries, we can calculate the height of the vertical intersection in meters as follows:

$$h = d * 1000 * tan(currentPitch) - \Delta height$$

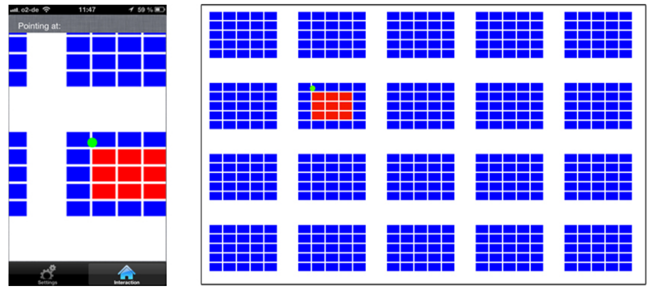

Figure 5: Right: The application displaying the targets and the current cursor position on the remote display. Left: The mobile application showing the detail view of the content around the cursor.

To transfer the geographical coordinates and the height of the intersection into display coordinates on the media façade, we map the calculated values relative to the upper left corner of the façade — starting (0,0) — with respect to its resolution. Hence, the coordinates are generally mapped as follows:

$$(x, y) = diplaySizePixel/displaySizeMeters * hitpoint$$

3.2 Managing Jitter

The goal of our work was to provide a system that utilizes sensor data of a mobile devise to allow interacting with large-scale urban displays by manual pointing. To realize this approach, we have to face additional challenges. (1) When controlling a pointer on a remote display by manual pointing, the natural tremor of the human hand introduces a jitter to the pointer, which reduced the accuracy of the interaction. This jitter naturally increases with an increasing pointing distance to the display. Due to their large size and therewith connected great visibility, this is especially an issue for large-scale urban displays such as media façades. (2) The inaccuracy of low cost GPS sensors influences — and might decrease — the accuracy of pointing and it might as well introduce an offset. (3) Furthermore, with an increasing interaction distance, the sensitivity of the pointer increases. The same movement angle of the pointing device causes a larger movement of the pointer on the display.

We address these issues by the following means: In order to counterbalance the introduced jitter, we introduced movement thresholds and we are smoothing the pointer movements over a time interval Δd. In addition to using the mobile device as a plain pointing device, we utilize the mobile device's screen to display a preview buffer of the media façade's content around the calculated cursor location (see Figure 4). This preview buffer serves as a detail view of the targeted area, through which the user can interact with the media façade's content by direct touch input on the mobile device's screen. The touch input is mapped and transferred to the actual façade. The size of the area around the pointer, which is displayed in the preview buffer, can be increased with the interaction distance or a decrease in the accuracy of the GPS signal. By this, we can counterbalance a decreasing accuracy of the pointing as well as an increased sensitivity of the pointer movement for increasing distance.

GPS Lens offers the user the possibility to temporarily freeze the content preview on the mobile device by pressing a button. The frozen image allows the user to interact with the displayed content without any jitter at all. Hence, the user can interact with a higher precision. By pressing the button again, the user can re-activate the pointing mode.

4. IMPLEMENTATION

The implementation is built upon common client-server architecture. We implemented the prototype of our client application for the Apple iOS platform, utilizing an iPhone5 as the mobile pointing device. The mobile client is connected over a wireless LAN connection to a Java application running on the façade. All calculations are performed on the mobile device itself. The target location of the pointing is continuously calculated on the mobile device for updates of the location or orientation of the device. After calculating the display coordinates of the pointing, the mobile device sends the coordinates combined with a user ID and a zoom level indicator to set the size of the content detail view over the UDP connection to the server application on the media façade which continuously updates the cursor position and sends back the content for the content detail view back to the mobile device. The façade boundaries are measured in advance and stored as presets on the mobile device. They are loaded and processed at application start-up.

5. USER EVALUATION

To evaluate the accuracy and applicability of the proposed technique, we conducted an initial user study with 6 participants (3 male, 3 female) with an average age of 31 years. As depicted in Figure 5, each participant had to select 20 randomly chosen blocks out of a grid structure displayed on a projected media façade with a size of 10x8m. The study took place on an outdoor plaza on our university campus under the open sky in order avoid shadowing of the GPS signal. The participants interacted from a distance of 15m, with an average GPS accuracy of at least 2m, which resulted in an average jitter of the controlled pointer of around +/-29cm. To interact with the projected display, and to select the targets, the participants used GPS Lens, running on an iPhone5. To minimize the possible delay that might be introduced by the network connection, we used a dedicated wireless LAN network to transmit the data. After completing the tasks, we asked the participants to fill out questionnaires about the accuracy of the pointing, as well as their experiences while using the system. For each question, the participants were asked to rate on a 5-point likert scale. The accuracy of the pointing was rated as good (3,17 on a scale from 1 = very inaccurate to 5 = very accurate). The participants further stated that due to content preview buffer shown on the mobile device, the inaccuracy of the pointing did not influence their interaction (2,17 on a scale from 1 = did not influence at all to 5 = strongly influenced). Asked about the ease of use, the participants rated the system as easy to use (4,3 on a scale from 1 = very difficult to 5 = very easy). They further stated not to feel uncomfortable while interacting (1,6 on a scale from 1 = very comfortable to 5 = very uncomfortable). In general, the system was rated throughout positive. Hence, despite the inaccuracy of the GPS signal, GPS Lens can be an applicable technique to control pointers on large-scale media façades.

6. DISCUSSION

The pointing accuracy of the proposed system strongly relies on the quality of the received GPS signal. Besides their lower accuracy in general, for low cost GPS sensors such as the ones built into mobile devices, the signal quality and therefore the location accuracy might be even more decreased by changes in environmental conditions, such as the weather. The quality of the GPS signal therefore remains a critical issue for the pointing accuracy and the applicability of the proposed system. Although we have introduced mechanisms to counterbalance this issue, the accuracy of the location — especially the altitude — needs to be further addressed. However, errors in the accuracy of the pointing also increase with the distance from which a user is interacting. Due to their large size and the therefore great visibility, media façades offer the potential to also interact from great distances. This raises the need to further investigate means to counterbalance inaccuracy introduced by the interaction distance and to further investigate the influence of the interaction distance at all.

For the sake of simplicity, while describing GPS Lens, we only considered one user at a time. Nevertheless, the system also supports multiple users interacting in parallel. Users are internally distinguished by a user ID, which is enclosed in every message send from the mobile device to the application running on the façades. Cursors for different users are displayed in different colors. Since the cursors are displayed on both the façades and the mobile device, each user can easily find the cursor belonging to him. Since each cursor occupies screen real estate, this approach is only applicable on media façades with a sufficiently high resolution. The number of cursors that can be displayed without occluding too much content therefore limits the number of parallel user.

7. CONCLUSION & FUTURE WORK

In this paper, we presented GPS Lens, an interaction technique to control a pointer on a large-scale urban display such as media façades with a mobile device. The presented approach utilizes the built in GPS sensor, compass and accelerometer of the mobile device to compute the pointing direction of the user. To overcome the limitations of current GPS sensors, we introduced a content preview of the media façade's content around the current pointer position on the local screen of the mobile device. We further report on the results of an initial user test, which revealed our approach as accurate and easy-to-use.

In the future work, we plan to conduct a full user study with different façade sizes from various interaction distances to verify the results from the initial user evaluation and to further investigate the influence of the interaction distance on the pointing accuracy. In this sense, we especially want to investigate pointing from very short, as well as from very large distances. Additionally, we want to further increase the accuracy of the pointing by incorporating further sensor data such as WLAN or Bluetooth fingerprints into the positioning. We further aim at generalizing the interaction client. Therefore, we plan to support the TUIO protocol (http://www.tuio.org) and make the client application publicly available as a general TUIO client. As is, GPS only addresses displays with a 2D form factor. Since a steadily growing amount of media façades comes with non-planar 3D form factors, we want to investigate how we can extend our system to support such media façades.

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