Data Visualisation Trends in Mobile Augmented Reality Applications

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ABSTRACT
According to Google Trends, mobile augmented reality (AR) apps will, after a brief hype-associated peak and decline, show again a more steady growth in the near future. Indeed, a review of currently available mobile AR apps suggests that they are embracing practical uses instead of simply showing off the capabilities of AR. Many of these apps are making information more ubiquitous without making the user necessarily aware of the data's origins, using graphics to represent multiple datasets. There has been however little research focusing on the trends in AR and the types of data visualisations used in mobile AR. The purpose of this paper is to fill that void by presenting an analysis of currently popular mobile AR apps on the market. Our findings from this small-scale investigation give an indication of the types of visualisation styles used in current mobile AR apps and highlight suggestions for how to make the information presented more relevant, for example by using better filtering methods.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: *Artificial, augmented, and virtual realities.*

General Terms
Design, Human Factors.

Keywords
Mobile Augmented Reality, AR, Mobile Computing, Human–Computer Interaction, HCI, Information Visualisation.

1. INTRODUCTION
Augmented reality (AR) in recent years has benefited from advances in mobile computing hardware, tracking algorithms and the increased availability of data through APIs. App developers can now easily create applications that implement AR by using frameworks, such as Qualcomm's Vuforia and Metaio [7].

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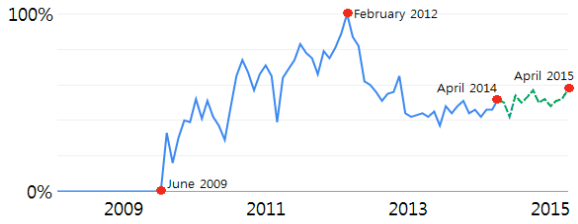

Figure 1. Google Trends graph displaying the relative number of searches for the phrase "augmented reality apps" per month from 2009 to 2015. The blue line represents historical data and the dotted green line represents Google's forecast.

The Google Trends graph for "augmented reality apps" (Figure 1) shows that the topic reached a peak in February 2012. A decline can be observed after that date, leading to a steadier trend from around 2013. The forecasted development until April 2015, based on a prediction by Google Trends from analysing historical data, suggests that interest will grow in the near future. The most popular queries that include the keywords "augmented reality" are "iPhone augmented reality", "android augmented reality" and "augmented reality apps". This suggests that people are interested in using augmented reality, especially on their mobile devices, beyond its initial hype around the time, when orientation sensors in smart phones became available, which made it possible to implement AR apps on standard off-the-shelf mobile devices.

The initial peak followed by a decrease and a steadier trend as seen in Figure 1 can be explained with the Gartner Hype Cycle (Figure 2). According to the methodology proposed by Gartner [3] emerging technologies enter "hype cycles" which contain five key phases. Technology Trigger is the first phase, where the proof-of-concept gains public interest from media attention. The second phase is Peak of Inflated Expectations, where a large number of

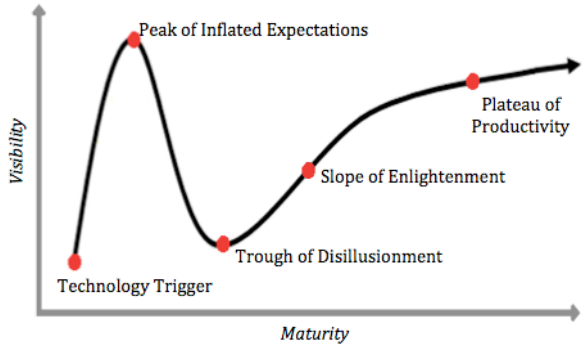

Figure 2. The Gartner Hype Cycle graph, depicting the phases an emerging technology undertakes to become mainstream.

successes are reported. The third phase is the Trough of Disillusionment; this is where public interest in the technology falls, due to the technology not living up to its expectations. The fourth phase is the Slope of Enlightenment, this is where the technology is coming out of the trough and a wider audience understands it. The Plateau of Productivity is the phase when the technology becomes mainstream and therefore a viable product.

Currently popular mobile augmented reality applications [10] appear to include practical uses, such as finding restaurants with good reviews, rather than show-off AR features, which was the case for many AR apps emerging during the peak of this technology. This further suggests that mobile AR apps have gone past their hype stage.

From a research perspective, it seems that mobile devices are becoming a more promising platform for AR technology, demonstrated through a recent analysis of ISMAR Proceedings [12]. The analysis found that published research papers on mobile AR are becoming increasingly popular, which authors attribute to the fact that the mobile device platform already has a large number of users, thus making it an appealing platform for researchers and developers alike.

Presently, mobile apps are being designed to use data ubiquitously, without making the user necessarily aware of where the data came from or providing raw data [2]. Information available through the device's sensor can be combined, such as using accelerometer and GPS data to find the position and direction that the user is facing, which is represented in Google Maps as a blue dot with an arrow. Visualising information in such a way is important as it prevents overloading the user with information and makes applications more intuitive to use, particularly on the mobile platform where screen space is limited. The implementation of such visualisations will gradually become easier due to advances in computer graphics APIs [1].

Although there is a large body of research on mobile AR [5, 8] and visualisations on mobile apps [1, 2, 6], there appears to be a lack of research regarding the use of visualisation styles and techniques in mobile AR apps. To address this gap, we present the findings from an analysis of current trends in visualising data on mobile AR apps and discuss potential visualisation techniques that could be explored to improve the usability of mobile AR.

2. METHOD

Due to the large amount of mobile applications on both Apple's App Store and the Google Play Store, we limited the apps included in our analysis to popular applications reviewed by a reputable technology review website. Therefore, the mobile applications that implement AR were chosen from a recent review article published on Digital Trends in March 2014, which presented a list of the top 20 mobile AR applications for Android and iOS [10]. Not all of the applications listed in this review were truly providing data visualisations as the list also featured some games and marker-based AR applications. Therefore, the following criteria proposed by Kosara [4] were used to identify the applications that included data visualisations: (1) The data must be non-visual data in order for it to be considered as a data visualisation. If the data itself is an image and it is being treated as such by the application, then it is not visualising the data. (2) The application produces an image representation of the data to communicate what the data is. (3) The visualisation needs to be readable by the user. Images should be readable and understandable. The applications that did not meet these criteria were not further considered, leaving a total of 9 apps that were included in our analysis: Acrossair, Augmented Car Finder, Google Sky Map, iOnRoad, Layar, Lookator, Sunseeker, Wikitude, and Yelp Monocle.

To assess the types of data visualisations employed in the applications we used Shneiderman's Task by Data Type Taxonomy (TTT) [9]. This allowed us to determine the type of data being visualised as well as the tasks that could be performed to manipulate the data. The TTT can be presented as a table, with the data types displayed vertically on the far left column and the tasks being displayed horizontally across the very top. The data types proposed by the TTT are: 1-, 2-, 3-dimensional data, temporal and multi-dimensional data, and tree and network data. The tasks are: Overview, Zoom, Filter, Details-on-demand, Relate, History and Extract.

The selected apps used a combination of 2- and 3-dimensional data. Acrossair, Augmented Car Finder, iOnRoad, Layar, Lookator, Wikitude, and Yelp Monocle all visualised 2-dimensional data, as they displayed the position of points of interests as well as their distance. Google Sky Map and Sunseeker both visualised 3-dimensional data as they showed where items were located in 3-dimensional space based upon the user's position. For the remainder of our analysis we focus on the tasks to develop a better understanding of the data visualisation styles and their associated control elements used across the selected apps.

3. TASK BY DATA TYPE TAXONOMY

In this section we present our findings from comparing the apps chosen in the methods section to the tasks described in the TTT.

Table 1. Overview of each app's support for the tasks (far left column). 1 = Acrossair, 2 = Augmented Car Finder, 3 = Google Sky Map, 4 = iOnRoad, 5 = Layar, 6 = Lookator, 7 = Sunseeker, 8= Wikitude and 9 = Yelp Monocle.

	1	2	3	4	5	6	7	8	9
Overview	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zoom	✓	×	✓	×	×	×	×	×	×
Filter	✓	×	✓	×	✓	✓	✓	✓	✓
Details-on-demand	✓	✓	×	×	✓	×	✓	✓	✓
Relate	×	×	×	×	×	×	×	×	×
History	✓	✓	✓	✓	✓	✓	×	✓	✓
Extract	✓	✓	×	✓	✓	×	×	✓	✓

3.1 Overview

Overview allows the user to gain a complete view of the items contained in a particular data set or the entire collection.

Our analysis revealed that 7 of the 9 apps use a type of overview, which we refer to as *fishbowl view*. This view provides a collection of data surrounding the user, which is overlaid over the live camera feed (e.g. Lookator, Figure 3c) or an image (e.g. Google Sky Map, Figure 3a). It seems that the fishbowl display method is popular in AR apps as it provides a very natural and intuitive form of viewing a collection of points of interests (POIs).

(a) (b) (c) (d) (e)

Figure 3. Screenshots of (a) Google Sky Map, (b) Sunseeker, (c) Lookator, (d) Layar, (e) Yelp Monocle.

The second most common overview method, which we found in 6 of the 9 apps, is a 2d *map view*, which shows an overview of items such as POIs on a map view. Five of these apps included a fishbowl as well as a map overview to gain a more consolidated view of the data. These apps allow users to access the map view mode via a menu button, except for Acrossair, which uses the orientation of the phone to automatically switch between fishbowl view and map view.

Sun Seeker offers a solar *compass view*, in addition to the fishbowl view, which displays a 2d overview of the data that – similar to the map view – can be used to gain a consolidated overview.

3.2 Zoom

The zoom task allows users to access more detailed information about a certain dataset. In AR apps, zoom is typically employed to allow the user gaining further insight on a particular item.

Only 2 of the 9 apps offered zoom functionality in the camera view. Acrossair includes a slider to zoom, while Google Sky Map supports the pinch gesture for zooming.

All apps that offered a map view, described in the previous section, allow users to perform zoom operations on the map, but since our analysis focused on AR visualisation styles, this was not considered as a true support of 'zoom' in the analysis.

3.3 Filter

Filtering information is an important aspect, especially for mobile AR apps due to the small screen size. Filtering can minimise clutter on the display and can be used to only show the user information relevant to them.

Most of the apps that included this functionality only offered predefined filters. For example, Yelp Monocle provides users with predefined filters to only show restaurants or bars or both. These filters are accessed via toggle switches located at the bottom of the screen (Figure 3e). Only 3 apps offered filtering by a user-defined term (Wikitude, Acrossair and Layar).

In some cases no filters are required due to the limited scope of the data. For example, iOnRoad is only used to avoid hazards and to find a single POI. Two other apps, SunSeeker and Lookator used simple on and off slider buttons to control certain graphical elements shown in the AR view.

3.4 Details-on-demand

This task focuses on how specific details are retrieved. A particular item or groups of items can be selected and specific details about those items are shown.

In the Wikitude, Yelp Monocle, Acrossair and Layar apps, POIs are displayed using tiles, which contain basic information, such as the name of the POI, the distance and a rating. The POI tiles can be tapped on to bring up an information page which provides detailed information about a certain place, such as the phone number, address, rating from user reviews, location on a map and a link to the company's website.

One notable feature about Wikitude is that it combats information overload by allowing POIs that are in the same direction to be stacked. By tapping on the stack users can see a spread-out view of the items contained in the stack (Figure 4).

Figure 4. Screenshots from Wikitude that show how stacked information can be accessed.

Layar offers an alternative method of handling information overload by including graphical representations of the POIs in the form of small shapes (Figure 3d). The basic information is hidden until the device is directly facing a particular POI. The selected POI turns red when it is selected and at the bottom of the screen the basic information is shown in an information box.

Other apps did not include details-on-demand functionality as all of the details were provided in the main AR view.

3.5 Relate

Viewing other items of interest that are somehow related to the one selected (such as showing events run by the same organiser) can allow users to find potentially relevant information.

Finding related information is currently not supported by any of the analysed apps. The only possible method to find related information is by manually searching for it.

3.6 History

There are situations where the user needs to be able to undo or redo an action. By keeping a history of previous actions users can for example refine or repeat certain searches.

The majority of the apps supported viewing history. Methods to view history included a favourites list that contained either favourite POIs or searches (Wikitude, Yelp Monocle and Acrossair), recently viewed categories (Layar), previously joined networks (Lookator) and last location (iOnRoad).

Google Sky Map has a notable, unique approach to viewing history as it allows users to access historical AR views: users can find out what the universe looked like at a specific point in time, such as the position of the moon on February 11th, 1991.

3.7 Extract

Extract functionality allows users to obtain a piece of information that they desire and to save it in a format that can be used later without needing to open the app again.

Most of the apps do not include a feature to save information onto the device. Saving information is limited to sharing a POI on social media (Acrossair), saving phone numbers to contacts (Yelp Monocle), copying information to a text message (Augmented Car Finder) and taking a screen capture or photo (iOnRoad).

4. DISCUSSION

All AR apps included in our analysis were location-based and focused around either helping the user find the location of a specific POI or assisting with navigation.

Some persistent themes emerged in the user interface of certain apps. For example, Wikitude, Yelp Monocle, Layar and Lookator all implemented a similar style of representing information. These apps share a common theme of having a mini blip map displayed in one of the top corners and using tiles to represent the POIs displayed in the direction that they are located. Tiles are a common visualisation technique used among the aforementioned apps. Additional information about POIs can be displayed on the tiles, normally including the name of the place, distance, and a rating. Layar uniquely provided further details by requiring POI selection before displaying information, saving screen space.

We noticed a persisting trend with all of the apps in regards to the filtering of information. Most apps offer a form of filtering, but with little or no possibility for customisation. There seems to be an opportunity to make the information featured in mobile AR apps more relevant by offering better filter mechanisms. A promising direction might be to follow Google's approach for sorting search results based on user profiles [11]. Such an approach would allow AR apps to automatically provide more relevant and personalised augmented content.

5. CONCLUSION

We analysed 9 mobile AR apps that are currently popular and that visualise data in the form of an AR view. We compared each app against the TTT, a model proposed by Shneiderman [9] to assist with observing trends that the apps display in regards to the visualisation of data. Our findings indicate that there is a large focus on mobile AR apps visualising a combination of positional information (location, longitude and latitude) to conserve the limited screen space afforded by mobile devices, with the "fishbowl" view being the most common type of overview that in some cases is complemented by a 2d map view. We further found that there is little to no support for customised filtering, finding related information and saving. This points to an opportunity for providing more personalised AR data visualisations to display content that is of relevance to the user and their context.

Mobile AR developers should consider screen space in their future designs by combining data types to avoid clutter, provided the user can comprehend the visual representation. Furthermore, attention should be paid to the TTT model, as it can be used to inform designs and lead to a better end user experience.

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