# Augmented Reality Browser Survey

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## Abstract

*While mobile Augmented Reality (AR) browsers have become one of the major commercial AR application, real-world usage behaviour with this technology is still a widely unexplored area. We report on our findings from an online survey that we conducted on the topic and an analysis of mobile distribution platforms for popular Augmented Reality browsers. We found that while the usage of Augmented Reality browsers is often driven by their novelty factor, a substantial amount of long term users exists. The analysis of quantitative and qualitative data showed that poor and sparse content, the user interface design or the system performances are major elements influencing the permanent usage of this technology by early adopters.*



**Keywords:** *Augmented Reality, Technology Adoption, Survey, User Study, Usability, HCI*

# 1 Introduction

Augmented Reality (AR) has been a research field for more than two decades, originated from seminal works such as Caudell et al. [3] and Feiner et al. [8]. Over the recent years the emergence of more powerful smartphones and the fast development in tracking algorithms have leveraged the commercial development of the first Augmented Reality applications accessible to the public.

Notably, we have seen the rise of an equivalent application of (desktop) web browsers termed *AR browsers*: an AR browser is a generic augmented reality application proposing to display geo-located multi-media content using a virtual representation augmented on the vision of the real world (i.e. a camera-image in the context of smartphone technology). AR browsers generally access remote resources through web protocols and services (e.g. HTTP Methods, REST), index the content through media streams (termed *channels*, *layers* or *worlds*) and support a variety of MIME formats (html, image, audio, video or 3D model).

AR browsers are not per se new; earlier work such as presented by Feiner et al.[7], Höllerer et al. [10] or Kooper et al. [12] were already introducing the concept of multi-media browser in the real world, either in term of their specific user interface or their system architecture. Differently, the recent progress of pervasive technology (wireless and cellular network infrastructure, web software technology, powerful mobile devices) deliver now a simple way to access and use an AR browser on a mobile device, outdoor as well as indoors.

As the awareness of this technology is spreading rapidly in the mind of the public (but also on their own device), the usability and responsiveness of AR browsers has never been thoroughly analysed. Precisely, former studies have been generally limited to the testing of some of their components and features (previously developed by academic research), in the context of lab-controlled human factor studies.

In this technical report we describe a survey we conducted in July 2011 as a first step to gather more knowledge about the potential and interest of AR technology from the public. Complimentary, we also looked at the evolution and adoption of the technology that can be quantified from mobile distribution platforms, such as Android Market or Apple App Store, where AR browser applications can be access, rated or commented. Both of these tools offer us a wider vision on the user behaviour related to AR browsers.

After briefly summarizing previous work on this topic, we introduce the experimental design and results of our survey on AR browsers. Finally we describe our analysis of adoption and subjective comments of some of the

AR browsers available in popular mobile distribution platforms before concluding.

# 2 Related Work

The existing related work can be classified in to two groups: works that contribute to technical or conceptual ideas to the field of AR browsers and works that analyse and study human response to this technology and some of its features.

## 2.1 AR browser

The Touring Machine presented by Feiner et al. [7] introduced the concept of an AR multimedia platform (based on a tablet equipped with external GPS and an inertial tracking system) on which a user can tour a campus and access historical and practical information (the concept extended further in [9]). the NEXUS architecture presented by [10] defines a conceptual platform supporting a spatial model, network requirements, data delivery and presentation of virtual information in the real world. Similarly Kooper et al. [12] presented the Real-World Wide Web as an information space of World Wide Web that is perceived using Augmented Reality. In that context, Spohrer presented the idea of the Worldboard [25] a global infrastructure to associate information with places: content getting referenced with a GPS position (rather than a URL), and being visualized with Augmented Reality (rather than a 2D html renderer). Similar work have also explored non-visual direct augmentation such geo-located post-it [22] or audio augmentation [1].

Based on the recent developments of Web technology, Schmalstieg et al. [24] presented the concept of Augmented Reality 2.0 as the next evolution of Augmented Reality by applying concepts of Web 2.0 to the domain of Augmented Reality. In their paper they explained that the major advance of Web 2.0 was to create an infrastructure that allows people to participate and contribute own content consequently allowing all kinds of social platforms. They stated that for an Augmented Reality 2.0 environment a similar infrastructure has to be established and that interfaces need to be created, which support the spontaneous authoring of content in place for a wide range of users.

Over the last five years, we have seen more academic projects exploring the concept of AR browser on mobile. MARA [11] was one of the first sensor-based AR browser running on mobile phone. Lee et al. [14] describes different conceptual ideas of adding different layers of information on an augmented world and a research agenda in this area. The ARGON browser [17] introduces a new data format (KARML) for creating and authoring interactive AR content based on existing web ecosystem.

We have also observed a large emergence of commercial and open-source AR browsers, to only cite a few: Junaio [18], Layar [13], Wikitude [26], ARViewer [16], Sekai Camera [5].

## 2.2 User Survey

Dünser et al. [6] presented a comprehensive literature review of evaluation techniques in Augmented Reality and pointed out the current lack of more human computer interaction research and empircal studies in AR. Similarly, Zhou et al. [27] reported the magnitude of different research areas in AR from the leading conference in the field (ISMAR). They found that only 6% of all the accepted papers were user evaluation papers. Olsson and Salo have investigated users' perceptions of mobile AR like (not focusing on AR browser) and visual search applications [21]. They got responds from 90 participants from which 62 participants actually used mobile AR like applications. In their survey they identified curiosity and novelty value of AR as the main factor for trying out the applications and their instability as the main weakness.

# 3 Online Survey

In this section, we present the experimental design and result of an online survey we conducted from May to July 2011. We will use the term ARB to refer to AR browser.

## 3.1 Method

We used an online survey to collect data from early adopter of the ARB. It was advertised on several social media channels and via e-mail.

### 3.1.1 Participants

We recruited participants through social network sites (facebook, Linkedin, Twitter, discussion boards), mailing lists and postings on communication channels of ARB vendors. In total 77 participants (14 female) fully completed the survey, 118 partially answered questions. We report only the results from the completed responses. Most participants were aged between 20 an 40 years (Figure 1(a)).

### 3.1.2 Material

The data was collected with LimeSurvey[1]. Statistical tests were conducted with R[2]. Coding of qualitative data was done in Nvivo 9[3] and Microsoft Excel.

### 3.1.3 Procedure

Participants were informed about the purpose of the study and the approximate time needed to complete the survey. They were informed that the data was collected completely anonymously; no incentives for taking part in the survey were offered. Participants were asked to answer 28 questions separated in three question groups (namely user background, type and applications, and benefits and drawbacks). The complete questionnaire can be found in appendix A.

## 3.2 Results

We present results on selected sections of the survey including participants' backgrounds, usage behaviour, usage scenario, consumed media, feature quality, movement patterns, social aspects and reasons for discontinuing using ARB.

### 3.2.1 Demographics

The recruitment channels of the survey resulted in participants who can be seen as tech-savy people and early adopters of ARB. This is reflected in the demographics that show a high computer literacy and interest in technology of most participants (see Figure 1). The participants were allowed to describe their professional status with an open form item. We clustered them in the categories presented in Figure 2(a).

### 3.2.2 Application Background

While there are more than twenty ARB applications out there, three of them were noted as the most popular amongst the participants: Layar , Junaio and Wikitude (see Figure 2(b)). The browsers were mainly used on iOS (54%) and Android devices (42%) with only a few using other platforms. Participants did first hear about ARB mainly through websites an blogs (66%), followed

[1]http://www.limesurvey.org
[2]http://www.r-project.org
[3]http://www.qsrinternational.com/products_nvivo.aspx

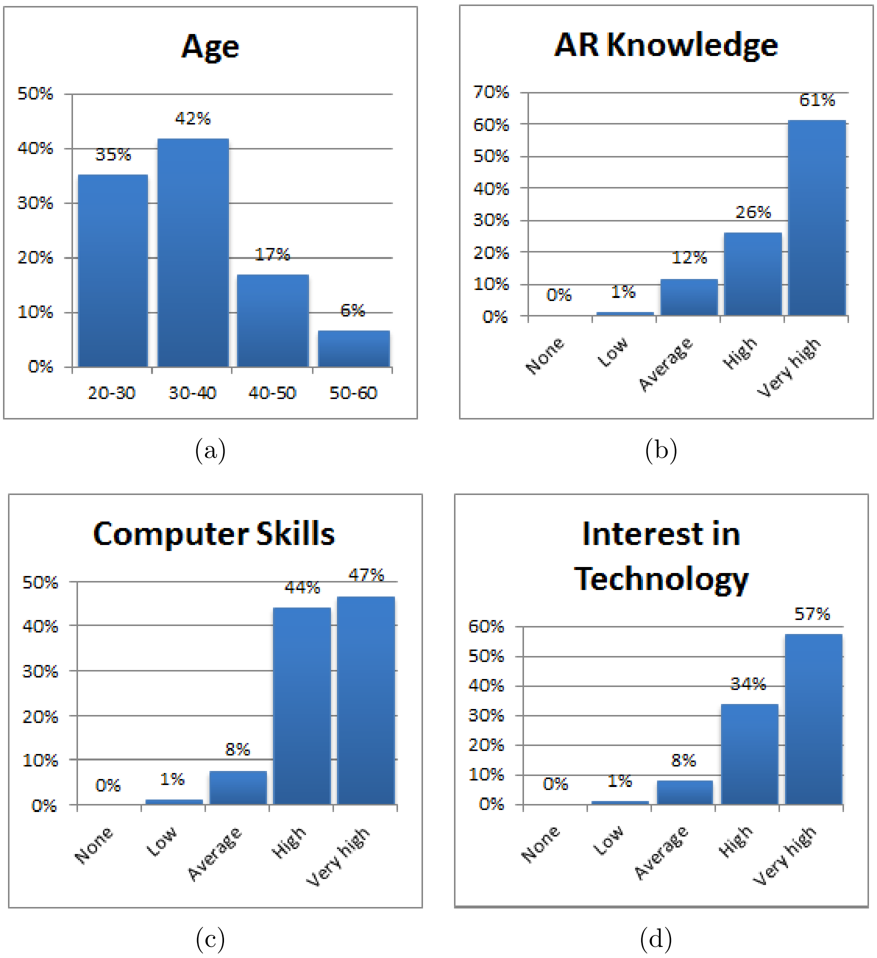
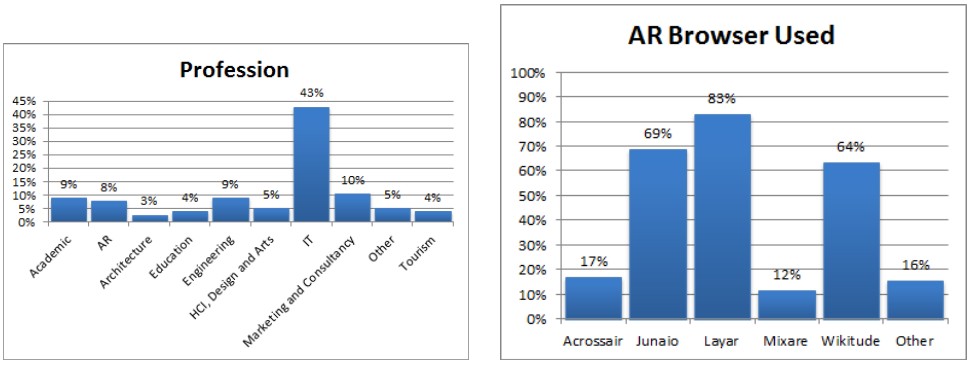



Figure 1: Overview of participant's age (a), knowledge of Augmented Reality technology (b), computer skills (c), and interest in technology (d).

by exploring the distribution platforms (Apple App Store, Google Android Market) (38%) and recommendations by friends (36%) (multiple choices were possible).

Mobile services that were used at least on a daily basis by the participants are Email (83%), Internet Browsing (79%), Social Network Services (71%) and calling (71%) (see Figure 3). Games were used on a less than daily basis by 61% (22% used them daily). Navigation applications like Google Maps were used by 58% less than daily and by 41% at least daily. Multimedia content was consumed by 48% daily and by 46% less than daily. These numbers reflect that the majority of the participants employed their phones primarily as communication medium and for general purpose browsing.




(a) (b)

Figure 2: Participants' professional status (a) and AR browsers used by participants (b).

### 3.2.3 Usage Time

The average session time with an ARB was between 1-5 minutes (see Figure 4(c)). Roughly a third of the participants (34%) tried out the browsers only a few times. On the other hand 42% used the browsers at least on a weekly basis (see Figure 4(a)). The period of active usage was also split into two groups with a third of the participants (33%) using the browsers only for a few days and a third (32%) using them for at least half a year (see Figure 4(a)). In the remainder of this report we therefore also looked for group differences between these high frequency and low frequency users as well as between these long-term and short-term users.

Usage frequency and usage duration have a strong positive correlation (Kendall's $\tau(75) = .55, p < .001$), see Figure 5.

As the gathered data was ordinal and failed normality tests (Shapiro-Wilk) we employed non-parametric hypothesis tests (Mann-Whitney U) for testing group differences. A Mann-Whitney U test indicated that professional AR users (AR knowledge: very high, $n = 47, 61\%$) used AR browsers significantly more frequently ($Mdn$="few times a week") than novel users (AR knowledge low to high, $n = 30, 39\%$) ($Mdn$="5-6 times", "every two months"), $U = 924.5, p = .01$. This test also indicated that professional AR users use ARB significantly longer (Mdn="3-6Months") than novel users (Mdn="1-3 Months"), U = 924.5, p = .01 (see also Figure 6).

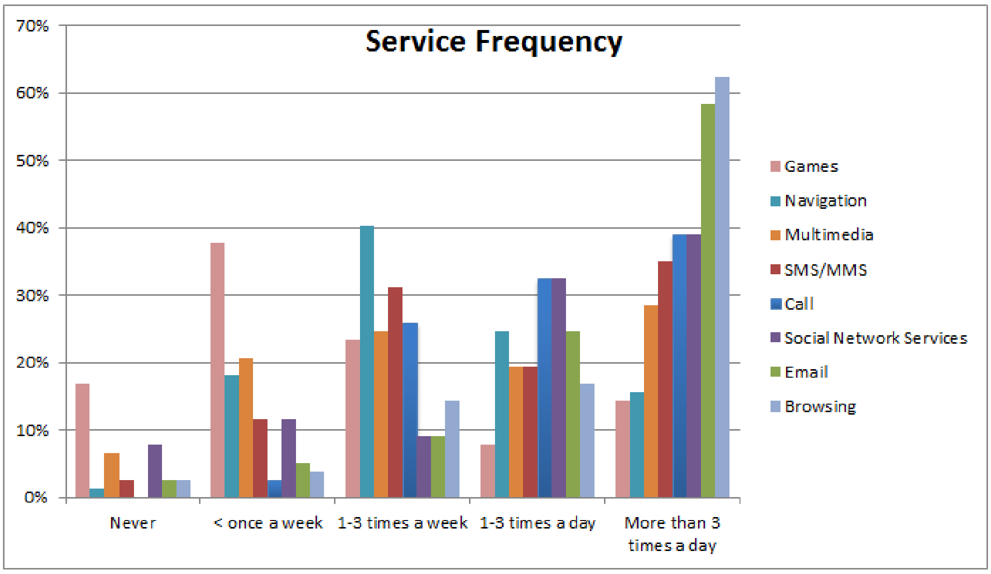
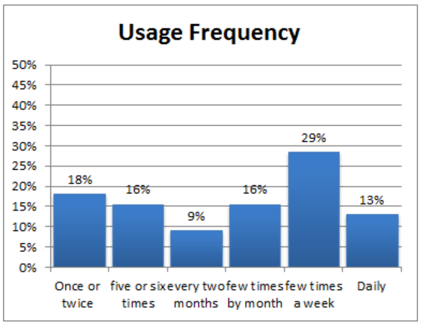
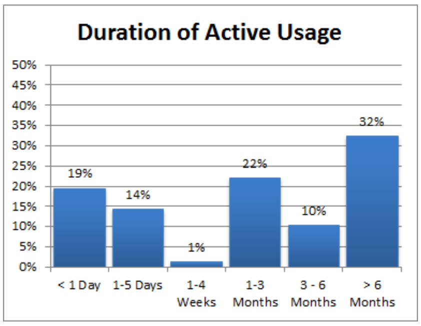


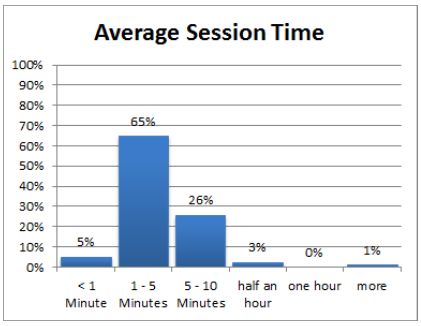

Figure 3: Frequency usage of Mobile Services.




(a)

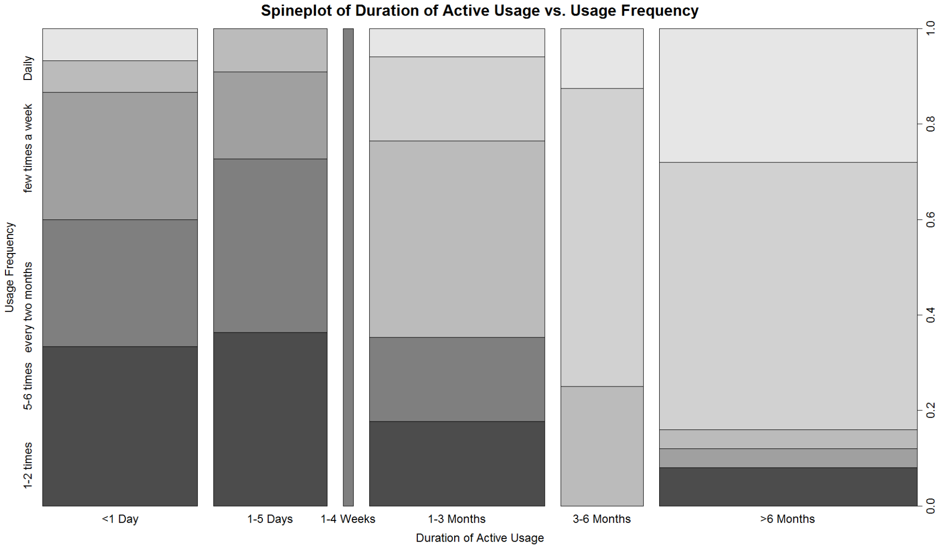



(b)

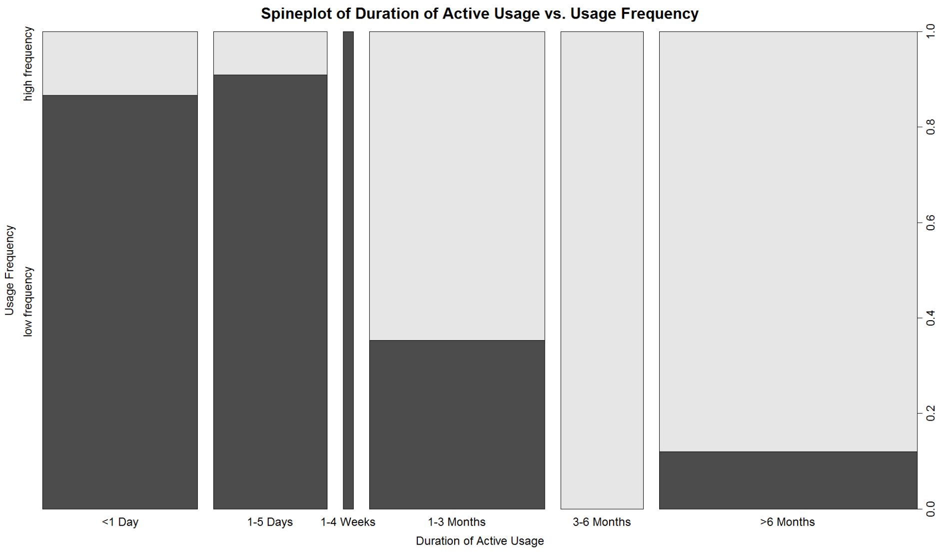



(c)

Figure 4: Usage frequency (a), duration of active usage (b), and average session time (c).

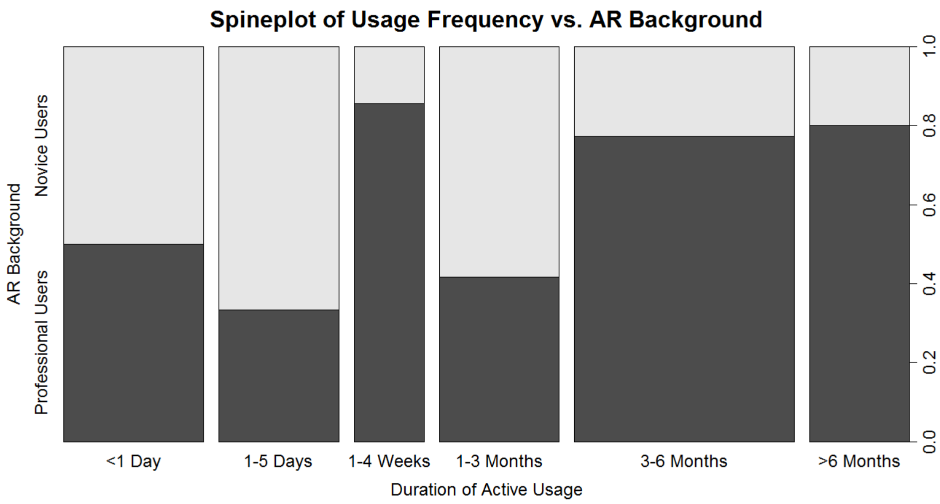



(a) Usage frequency and duration of active usage.

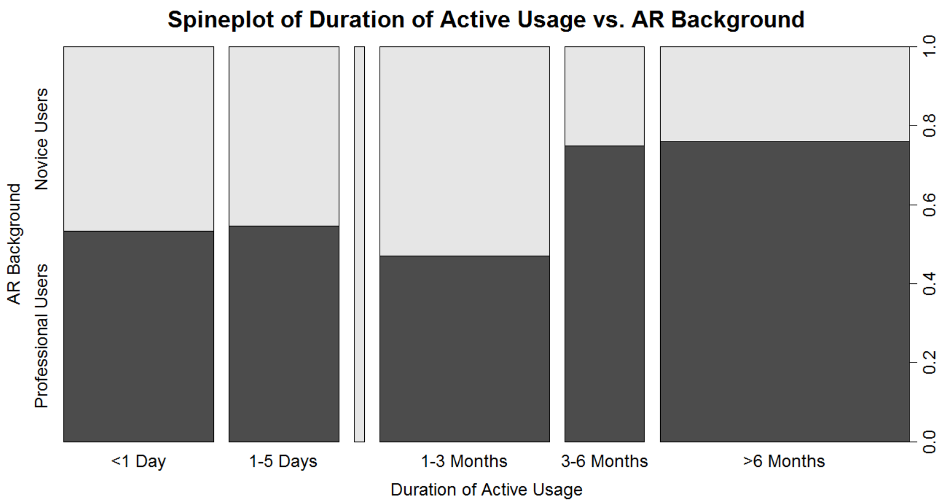



(b) Usage frequency collapsed into high and low frequency users and duration of active usage.

Figure 5: Usage frequency and duration of active usage with original (a) and collapsed frequency (b) categories.




(a) AR background and usage frequency.




(b) AR background and duration of active usage.

Figure 6: Spineplots for users with high and low AR background w.r.t. usage frequency (a) and active usage duration (b).

### 3.2.4 Usage Scenarios

Participants of our survey used the AR browsers most often for general purpose browsing and navigation (see Figure 7). 31% of the respondents also used the browsers for gaming, 39% in museum settings. The browsers were used outdoors by most (91%) and indoors by half (51%) of the participants. A third of the participants (27%) already used the browsers in a social group, 44% with a few friends, and 57% alone (multiple choices possible). There were no significant effects with respect to age, gender or AR expertise.

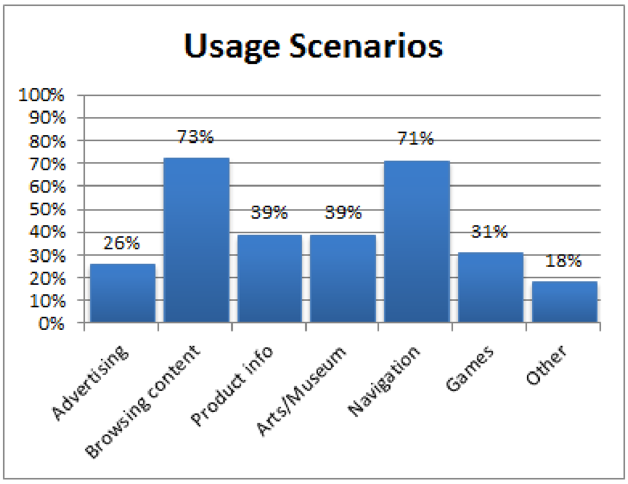



Figure 7: Usage scenarios.

Half of the responders rated browsers good to very good for accessing product information (44%) or guidance (47%), a third for browsing content (32%), advertising (31%) or museums (29%) but only 22% for gaming (see Figure ). However, a quarter to a third of the participants was still uncertain of their quality for advertising (26%), museums (29%), and games (29%). This might be explained by the relative low number of participants who used AR browsers in these settings. In contrast to the ratings of the current state of AR browsers (see Figure 8) most participants gave high to very high ratings for the potential of AR browsers in the various application domains (see Figure 9).

As the gathered data was ordinal we used a rank based correlation measure (Kendall's $\tau$). There are moderate positive rank correlations between current usage and usage potential ratings only for general purpose browsing and navigation (based on Kendall's $\tau$, two-sided, excluding "Don't know") (see Table 1). There are no significant correlations for the other application domains.

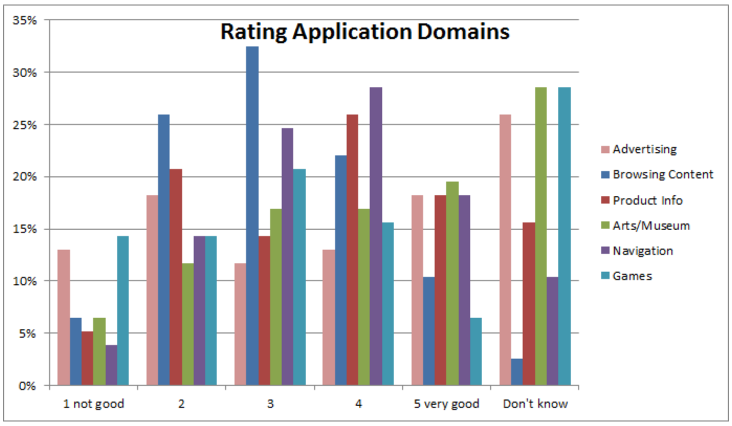



Figure 8: Rating of performance of current ARB for application domains.

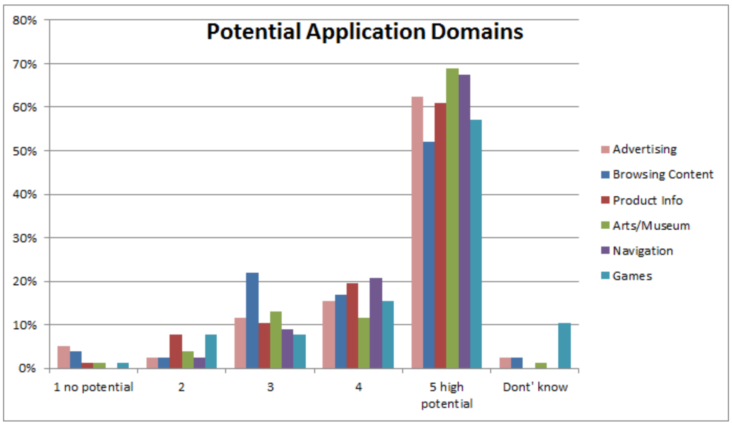



Figure 9: Rating of potential of ARB for application domains.

#### 3.2.5 Consumed Media

Most participants experienced *Point of Interests* (POIs) of textual form (77%), followed by 51% who experienced images and 43% of the users consumed 3D content. More complex web content (such as embedded webpages) and videos were experienced by only a third (27%) (see Figure 10).

#### 3.2.6 Feature Quality and Issue Frequency

Figures 11 to 13 show boxplots of rated quality of several features together frequencies of experienced issues with the same features.

A Kendall's $\tau$ test revealed moderate negative correlation between rating of feature quality and frequency of experienced issues for position accuracy, position stability (see Table 2).

| Domain | n | p-value | $\tau$ |
|---|---|---|---|
| Advertising | 75 | .23 | .12 |
| Browsing | 75 | **< .001** | .33 |
| Product Info | 77 | .934 | $-.01$ |
| Arts/Museum | 76 | .53 | $-.06$ |
| Navigation | 77 | **.017** | .23 |
| Games | 69 | .89 | $-.01$ |

Table 1: Kendall's $\tau$ rank correlation between current usage rating and usage potentials.

| Issue | n | Rating Mdn | IF Mdn | p-value | $\tau$ |
|---|---|---|---|---|---|
| Registration | | | | | |
| Position Accuracy | 76 | 3 | 3 | **< .001** | $-.42$ |
| Position Stability | 77 | 3 | 4 | **< .001** | $-.45$ |
| UI | | | | | |
| Interface Design | 77 | 3 | 3 | **< .001** | $-.44$ |
| Content Representation | 76 | 3 | 3 | **.001** | $-.32$ |
| Content | | | | | |
| Quantity | 75 | 3 | 3 | **< .001** | $-.40$ |
| Quality | 75 | 3 | 3 | **< .001** | $-.45$ |
| Device | | | | | |
| Battery | 70 | 3 | 3 | **< .001** | $-.41$ |
| Network | 76 | 3 | 3 | **< .001** | $-.50$ |
| Screen Size | 76 | 3 | 3 | **.004** | $-.27$ |
| Screen Quality | 75 | 4 | 2 | **< .001** | $-.44$ |
| Device Handiness | 76 | 3, 4 | 3 | **< .001** | $-.50$ |
| Device Weigth | 75 | 4 | 2 | **< .001** | $-.47$ |
| Other | | | | | |
| General | 76 | 3 | 3 | **< .001** | $-.38$ |

Table 2: Kendall's $\tau$ rank correlation between ratings of issue quality (low to high) and frequency of issues (never to very often). Interquartile range was 2 for all ratings and issue frequencies (IF Mdn: Issue frequency median).

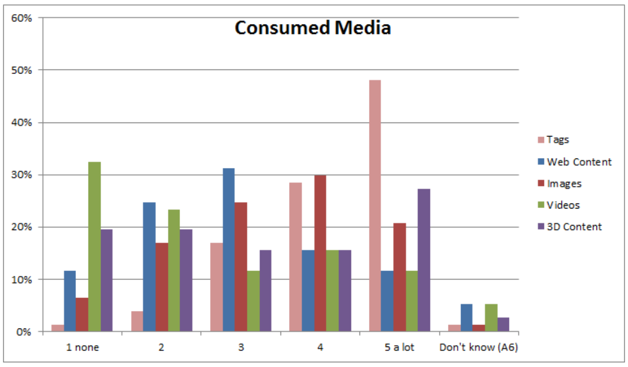



Figure 10: Type of consumed media.

For the above mentioned features (except for device handiness and weight which have a high rating with low issue frequency) low to modest ratings go along with modest to frequent experiences of issues.

A one-tailed Mann-Whitney U test indicated that professional AR users rated content representation significantly lower (Mdn=3) than novel users (Mdn=3, 4), $U = 511, p = .02$.

The test also indicated that frequent users rated position stability significantly higher than non-frequent users (see Table 3), as well as content representation. Frequent users rated content quantity, content quality significantly higher and experienced issues with content quality not as frequent as non-frequent users. In addition issues with content quality did not appear as frequent for frequent users than for non-frequent users (Mdn=3 for both groups), U=538.5, p=.047. For other issues no significant differences were detected.

| Rating | n | Mdn f | Mdn nf | p-value | $U$ |
|---|---|---|---|---|---|
| Position Stability | 76 | 3 | 2,3 | **.05** | 854.5 |
| Content Representation | 76 | 3 | 3 | **.01** | 921 |
| Content Quantity | 75 | 3 | 2, 3 | **.0026** | 861.5 |
| Content Quality | 75 | 3 | 3 | **.004** | 925.5 |

Table 3: Significant differences in feature quality ratings for frequent (f) vs. non-frequent (nf) users according to Mann-Whitney U test. Interquartile range was 2 for all ratings.

Looking at the differences between frequent and non-frequent users, a one-tailed Mann-Whitney U test also indicated that long-term users rated position stability, content representation significantly higher than non-frequent users (see Table 4). For content quantity and content quality there was only a

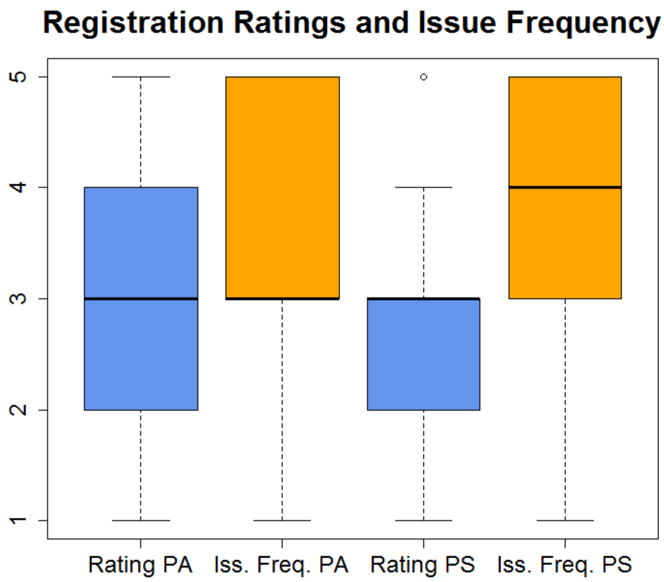



Figure 11: Registration quality rating (blue) and issue frequency (orange). PA: Position Accuracy. PS: Position Stability.

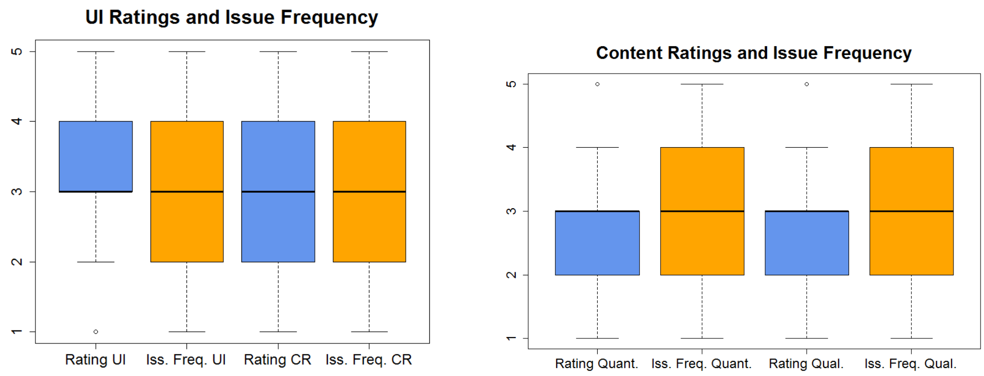
weak significant difference. In addition battery issues were experienced more frequent for long-term users ($Mdn = 4$) than for short-term users ($Mdn = 3$) $n = 70, U = 784.5, p = .018$, as well as device weight issues ($Mdn = 3$ for long-term, $Mdn = 2$ for short-term users), $U = 873.5, p = .023$.

| Rating | n | Mdn lt | Mdn st | p-value | $U$ |
|---|---|---|---|---|---|
| Position Stability | 76 | 3 | 3 | **.02** | 897 |
| Content Representation | 76 | 4 | 3 | **.008** | 930 |
| Content Quantity | 75 | 3 | 3 | .092 | 568.5 |
| Content Quality | 75 | 3 | 3 | .07 | 556 |

Table 4: Differences in ratings in feature quality ratings for long-term (lt) vs. short-term (st) users according to Mann-Whitney U test. Interquartil range was 2 for all ratings.

### 3.2.7 Movement Patterns

Most of the users were experiencing the application while standing at the same position (78%), combined with rotations (90%). Small movements ($<$




(a) UI: User Interface. CR: Content Representation.

(b) Quant: Content Quantity. Qual: Content Quality.

Figure 12: User interface (a) and content related (b) ratings (blue) and issue frequency (orange).

$5m$) were carried out by 57%. Large movements ($> 5m$) or multiple large movements were conducted by 48% respectively 42% (see Figure 14).

A Chi-squared independence test with Yate's continuity correction indicated significant differences between frequent and non-frequent users for standing combined with rotation, $\chi^2(1, n = 77) = 5.47, p = .02$ (see Table 5) and multiple large movements ($> 5m$) combined with rotation $\chi^2(1, n = 77) = 5.94, p = .01$ (see Table 7).

There was also a significant difference in multiple large movements ($> 5m$) combined with rotation between long-term and short-term users, $\chi^2(1, n = 77) = 10.05, p = .002$ (see Table 7) and professional and novice AR users, $\chi^2(1, n = 77) = 5.55, p = .02$ (see Table 8). Furthermore, between professional and novice AR users there were significant differences for small (1-5m) movements combined with rotation $\chi^2(1, n = 77) = 4.81, p = .03$ see Table 10), as well as a weak significant difference for larger movements ($> 5m$) combined with rotation $\chi^2(1, n = 77) = 3.35, p = .07$ (see Table 9).

This analysis showed that while ARB were used by half of the participants also with large movements, frequent and long term users tend to restrict their movements more then non-frequent or short term users.

### 3.2.8 Social Aspects

The majority of the subjects did not experience regular social issues when using ARB and agreed to use the browser despite potential social issues (see Figure 15). The majority also did not experience situations (as shown in

| S+R | frequent | non-frequent |
|---|---|---|
| no | 43 | 26 |
| yes | 1 | 7 |

Table 5: Contingency table for standing combined with rotations (S+R) grouped by usage frequency.

| MML+R | frequent | non-frequent |
|---|---|---|
| no | 24 | 8 |
| yes | 20 | 25 |

Table 6: Contingency table for multiple large movements ($> 5m$) combined with rotations (MML+R) grouped by usage frequency.

| MML+R | long-term | short-term |
|---|---|---|
| no | 21 | 11 |
| yes | 12 | 33 |

Table 7: Contingency table for multiple large movements ($> 5m$) combined with rotations (MML+R) grouped by active usage duration.

| MML+R | pro | novice |
|---|---|---|
| no | 7 | 25 |
| yes | 23 | 22 |

Table 8: Contingency table for multiple large movements ($> 5m$) combined with rotations (MML+R) grouped by AR background.

| ML+R | pro | novice |
|---|---|---|
| no | 10 | 27 |
| yes | 20 | 20 |

Table 9: Contingency table for larger ($> 5m$) movements combined with rotations (ML+R) grouped by AR background.

| MS+R | pro | novice |
|---|---|---|
| no | 12 | 32 |
| yes | 18 | 15 |

Table 10: Contingency table for small (1-5m) movements combined with rotations (MS+R) grouped by AR background.

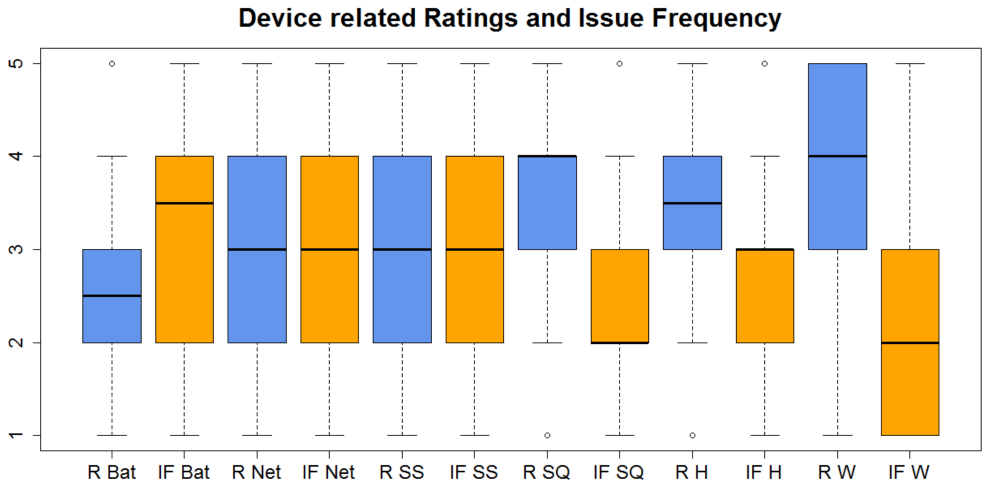



Figure 13: Device related quality rating (blue) and issue frequency (orange). Bat: Battery. Net: Network. SS: Screen Size. SQ: Screen Quality. H: Device Handiness. W: Device Weight.

Figure 16) in which they refrained from using the application. A one-tailed Mann-Whitney U test indicated that female users refrained from using AR browser in crowded situations significantly less often than male users (Mdn=1 for both groups), $U = 532, p = .03$. No other significant effects were observed.

#### 3.2.9 Qualitative Feedback

Subjects were asked to provide reasons for withdrawing their uage of AR browsers if they did so; 31 (40%) of them provided free text answers. The answers were coded in a data-driven fashion [4] into 12 categories with 46 items. An overview about the reasons for discontinuation of ARB usage can be seen in Figure 17(a).

Some answers for categories were:

1. Registration:
    - "Sensors are insufficient for suitable overlay"
    - "It is not so reliable. Often the compass and the gps doesn't work"
    - "Not useful as it was not spatially accurate"
    - "Lack of relevance to physical surroundings"
2. Content:

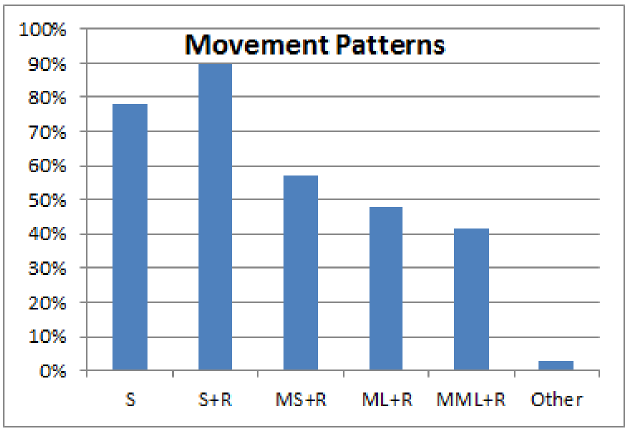


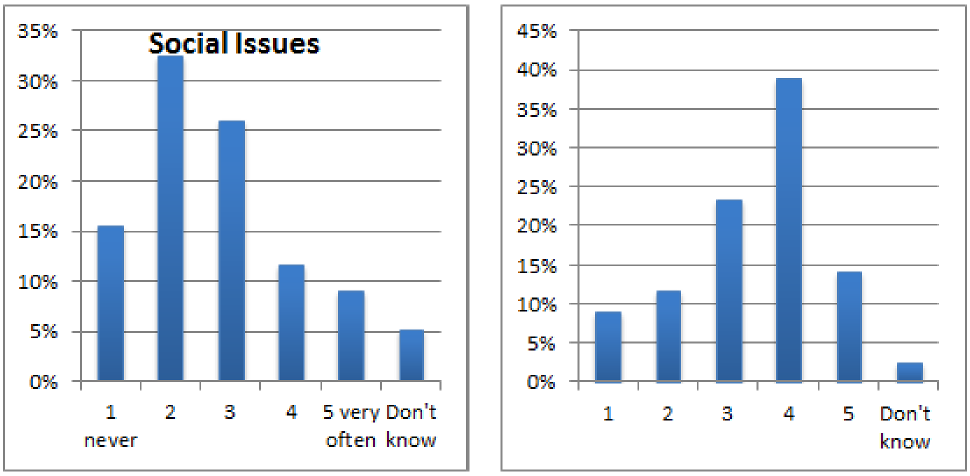

Figure 14: Movement patterns. S: standing. S+R: standing combined with rotation. MS+R: small (1-5m) movements combined with rotation. ML+R: larger movements ($> 5m$) combined with rotation. MML+R: multiple large movements ($> 5m$) combined with rotation.

- "Nothing interesting to see"
- "No interesting content"
- "There's not much useful information"

3. Maps:
   - "I don't find it as convenient as just using something like Google Maps"
   - "Google Maps is easier"
   - "No advantage over Google Maps, less useful than Google Maps + internet recommendations for e.g. restaurants"

4. Missing purpose:
   - "Not much real use-cases"
   - "Generally I don't find them very worthwhile (to use privately)"

5. Visual clutter:
   - "Information is not really helpful to me, because to it is to cluttered"
   - "Too many POI one over the other"
   - "UI is always cluttered, information is not well structured"




(a) Number of occurences of experienced social issues with AR browsers (5 point Likert scale. 1: completly disagree. 5: completly agree).

(b) Agreement to use AR browsers despite potential social issues (5 point Likert scale. 1: completly disagree. 5: completly agree).

Figure 15: Times social issues were experienced (a) agreement to use AR browser despite potential social issues (b) ratings.

6. Concept:
   - "There was no need to overlay icons on top of video"
   - "It is annoying to hold up the phone all the time" (translated from German)
   - "Holding up phone is unnatural, dangerous in certain circumstances"

In addition, subjects were asked to provide ideas for future features of ARB; 37 (48%) of them provided free text answers. The answers were coded into 11 categories with 55 items. An overview can be seen in Figure 17(b).

Some answers for each category were:

1. Registration
   - "Need to find a way to calm down the jumpiness!!! Make it more exact"
   - "Better location accuracy, robust POI display"
   - "Better location, better overlay on real world objects"
   - "Vision-based AR"

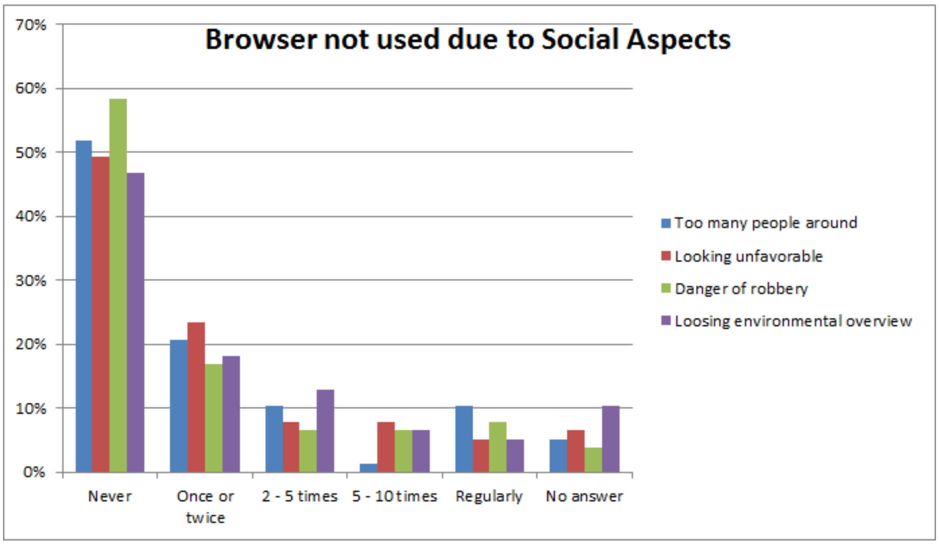
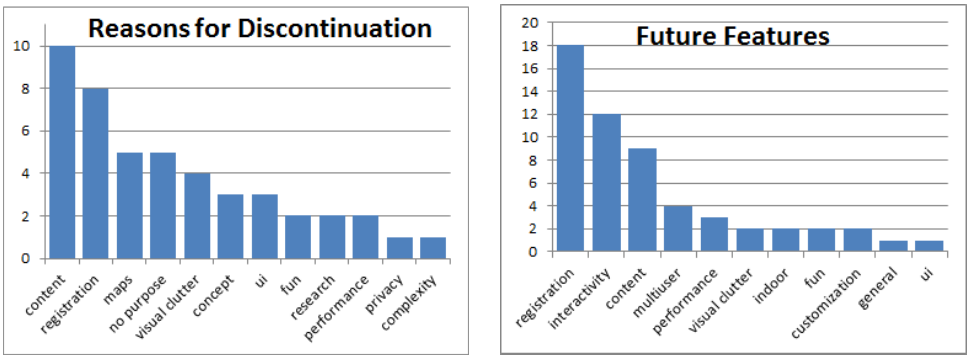



Figure 16: Times AR browsers were not used in several situations.

2. Content
    - "Interesting stuff to see"
    - "More Content"
    - "User-generated content"
    - "Better designed content, more variety in regards to types of documents/files, more tools"
3. Interactivity
    - "More interactive features (comments, rating, participating)"
    - "More interactivity"
    - "3D interactivity"
4. Visual clutter
    - "Well-arranged content, techniques for remove clutter"
    - "More interactive, better filters"
5. Multi-user
    - "IM integration to contact a person if located nearby in the real time"
    - "Multiuser stuff"




(a) (b)

Figure 17: Reasons for discontinuation (a) and requested future features (b).

### 3.3 Discussion

Our survey has mainly collected feedbacks from computer literate persons. Similar to other emerging technologies, like location-based services [19], users of ARB are early adopters who have a high interest in technology.

On one hand a third of the participants used the ARB just for a few day (five days or less: 33%) and less than six times (34%), indicating a large group of the participant's merely tried out the browsers. On the other hand a 42% of the participants used the the ARB for at least 3 months and 42% at least weekly, indicating a that there is a regular user base of ARB that use them for mere than just 'trying out'. Similar to the usage patterns of other mobile applications [2] ARB are typically used only for a few minutes per session.

Besides general purpose browsing, participants used ARB for navigation purposes most frequently. This could indicate that participants used the ARB as alternative to map-based navigation methods. While the participants gave high ratings for the potential of ARB for wide range of application scenarios the ratings of the current performance of ARB in these domains (except general purpose browsing and navigation) did not correlate. This could indicate that people have high expectations in the ARB which are not met yet.

Augmented Reality leverages it's potential with accurate spatial registration of virtual content to real-world scenes in real-time. If the geometric registration between real and virtual objects is weak the semantic link between the two might become unclear as well. Currently, the consumed content in ARB is mainly of simple form, such as textual tags (77%) or images (51%). Even if 3D content is available (as consumed by 43% of the participants) it is still mainly registered with 2 degrees of freedom (longitude, latitude). This can result in meaningless or cluttered overlay of content on the ARB screen. Our study results indicate that content and registration issues are a factor for discontinuing the use of ARB. But even frequent users do rate the quantity or quality of available content only as average. Another common issue with the use of ARB is the large power consumption that results in perceived issues with the battery life of mobile devices. Registration, content and the interaction with that content were also among the most requested features for future versions of the ARB.

ARB were used by half of the participants also with large movements, but frequent and long term users tend to restrict their movements more then non-frequent and short term users, possibly adapting to the difficulties that arise when reading the information while moving. Previous studies investigated the reading performance of simple text while walking (e.g., [20, 23]) or automatic determined text readability over different backgrounds ([15]) but the impact of a changing camera image together with a possibly jittering augmented information while walking has not been investigated so far and should be explored further.

Generally, participants experienced no social issues when using ARB regularly.

# 4 Mobile Distribution Platform Analysis

To complement our online survey we analysed the customer feedback available from the two dominant mobile software distribution platforms: The Apple App Store (AS) and the Google Android Market (AM). We looked at the ratings and user comments for both stores and thus for some of the most popular AR browsers. As rating and commenting require users to authenticate, being limited to only one entry, this filtered information (no profanity, nominative) can provide us some interesting insights in the popularity of these AR browser applications.

## 4.1 Method

To collect the data, for the Apple App Store we used the AppReviewsFinder software[4]. For Android Market we used the data from the official Android Market homepage [5]. Data from both stores were gathered in June 2011 and represent the feedback given until then. Please note that the type and amount of information that can be retrieved from both distribution platforms are not symmetric. For example you can access country specific statistics for the Apple App Store while there are no country specific statistics available for the Google Android Market. It was also not possible to retrieve all user comments from the Android Market, limiting our analysis for this type of data to the Apple App store. Certain precise information are available to the developers of the software only (e.g., total numbers of downloads) and official information are only a rough indicator. We consequently decided to not evaluate some of these information. The presented numbers of downloads is also biased by the fact that some smartphone manufacturers have pre-installed some of these AR browsers but also are included in the total number of downloads, despite the fact that users never explicitly downloaded them. We also restricted our analysis to solely focus on the current state of AR browsers on these distribution platforms at a specific period of time, and not considering the temporal aspect (e.g., trends over time for download, comments, adoption for specific countries).

## 4.2 Results

We describe here our review of the ratings in both distribution platforms and a deeper analysis of the comments in the Apple App Store for different ARB.

[4]http://www.massycat.co.uk/iphonedev/AppReviewsFinder/
[5]https://market.android.com

### 4.2.1 Ratings

At the time of our study, we collected - for the different AR browsers - about 70.000 ratings for the App Store (multi-countries); about 30.000 ratings for the Android Market were available. Both mobile distribution platform use a 5 stars rating system (5 stars are very good, while 1 star is very poor).

On the AS we identified five ARB that are prominent in terms of users-base and countries they are available. Based on the numbers of ratings they are SekaiCam (27364 ratings), Layar (23385 ratings), Acrossair (9150 ratings), Wikitude (5443 ratings) and Junaio (3382 ratings). Oppositely, there are only two ARB that achieved more than 1000 user ratings on the AM: Layar and Wikitude. For both the number of ratings nearly matches the ones from the Apple App Store.

The analysis of the gathered data showed that the average rating for all major ARB was very similar (overall average 2,49 stars) and also the differences in the average rating can be nearly ignored (Max: Layar 2,62 stars, Min: 2,39 stars Junaio). While examining the Android Market data it showed up that except SekaiCam all other applications rated significant higher on the Android platform (average 3,65), which can be caused by stability problems on the certain platforms or certain expectations that are platform dependent (see Figure 18). As an example many iOS users have higher expectations regarding the implemented interface and the application quality as both have so far been on a higher level for applications running on iOS.

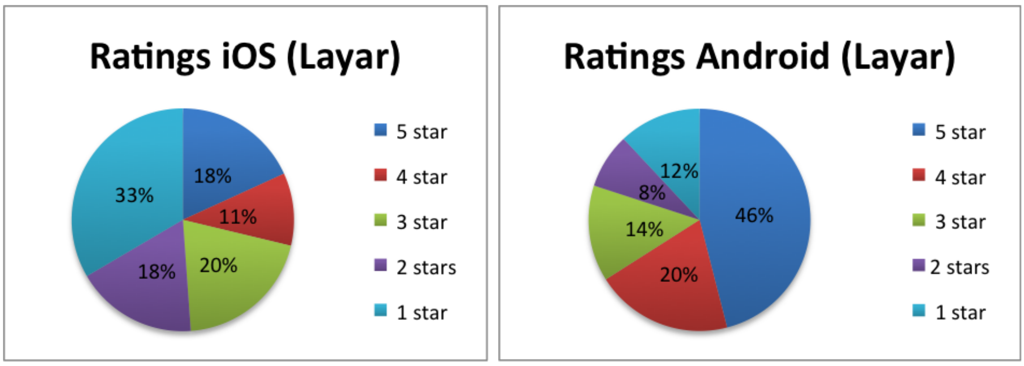



Figure 18: Difference of user ratings om both platforms based on Layar as example case (5 stars are very good, while 1 star is very poor).

The average rating is always the results of rather mixed ratings for all examined ARB as the standard deviation ranges from 1,38 (Wikitude) to 1,59 (Junaio) saying that many users gave very high or very low scores.

Based on the users feedback in the Apple App Store it is also possible to analyse the difference in ratings between countries. In general there is for all applications only a small deviation in the rating between the countries (Min. Layar SD = 0.38, Max. Junaio SD = 0.63). This is also reflected in the standard deviation of the ratings for each country, which are all nearly the same and showed that there are no significant effects that are based on cultural differences.

However, it is noticeable that for all countries with more than 100 ratings (to compensate outliers) South Korea was always in the top group of top ratings, while France was always among the countries with the lowest average ratings. But since the differences between the best and the worst ratings per country were only minor this can only be seen as a weak trend. Furthermore, it SekaiCam got in average lower ratings in German speaking countries (Germany and Austria) but again the difference was small (though noticeable) and could indicate content issue or a bad localization. Based on the total number of ratings the most feedback came from users out of the USA followed by Japan, UK, Germany, South Korea and France with each application getting a relatively big number of ratings from the country of origin (Acrossair/UK, Junaio/Germany, Layar/Netherlands, SekaiCam/Japan and Wikitude/Austria).

### 4.2.2 Comments

We analysed 1135 comments from some of the most common western languages (English, German and French language) for all major ARB on the Apple App Store.

Analyzing the content of the comment, we categorized them in different groups, removed the basic and rhetorical liking type of comments, focused strongly on comments with a negative connotation or arguing about specific aspect of ARB. In result, we obtained 5 major clusters (some with subgroups): applications crashes, content availability, user interface and visualization (contains comments about the graphical interface as well as the used visualization of the content), tracking quality and general performance (contains comments regarding perceived performance, problems with network performance or comments regarding power consumption). An analysis regarding the occurrences in our dataset can be seen in Figure 19.

In the following we present a deeper analysis of the clustered comments.

1. Application crashes: From the total amount (1135 comments) 225 comments contained complaints about regular crashes. This is by far the biggest category of complaints, which is also an indicator while the ratings were so mixed between 1 star and 5 stars as most people with repeating crashes gave 1 star. It shows up in the comments that es-

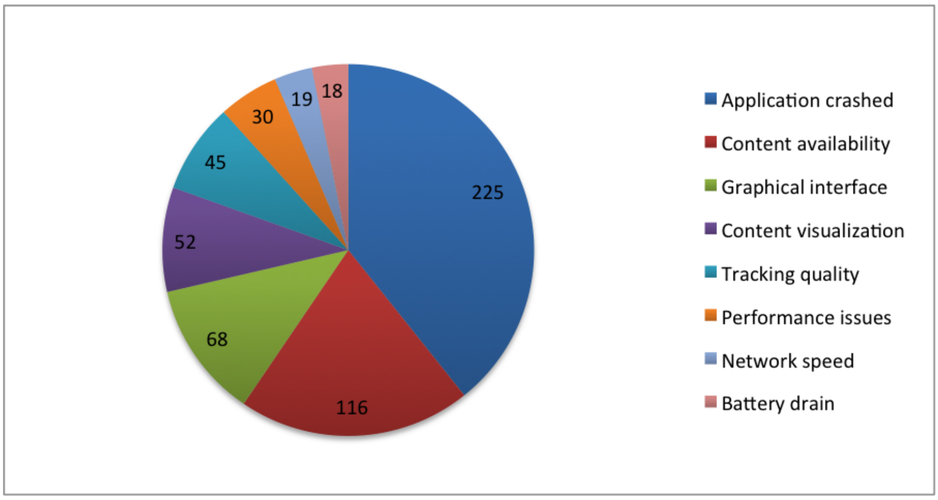



Figure 19: Result of clustering the total 1135 comments of the Apple App Store by focusing on negative connotations.

pecially maintaining software version for every new system version or new hardware can be quite challenging.

2. Content availability: The second biggest category of complaints was regarding the availability of content. Many people expressed their disappointment with the amount and quality of available content. This ranges from no available content at all ("There were hardly any Points of Interest in Charlotte, NC") to very limited amount of content ("I looked for POI near me and all it came up with was a Post Box in the next street"). Furthermore many users had certain expectations regarding the content that were not fulfilled. Some users complained that the content is still not up to date ("Then I tried supermarkets, and it found one non-existent supermarket in our town") or needs to be paid.

3. User interface and visualization: Another problem that was raised in several comments was the quality of visual representation. Firstly, in form of the graphical interface (menus and buttons) that was considered several time as not very intuitive or not nice enough compared to other iOS apps. Furthermore, many people complained about the visualization of the displays content (such as POIs), which can become unreadable if to many POIs are in close proximity ("It stacks up results until you need to point at the sky to read them") or have a general low quality ("Can't wait until AR has real graphic experiences").

4. Tracking quality: Some people addressed in their comments problems with positioning accuracy that are usually caused by a bad GPS signal or an inaccurate orientation estimate ("I played with this app near my home town and it misidentified the location of our closest hospital - it was WAY off").

5. General performance: Only a few people had problems with the general performance or the speed of the necessary network connections. However, some people suggested a caching mode, which would help users in foreign countries (e.g. tourists) to use the application even if they don't use a (expensive) 3g connection by prefetching and caching the results when a connection is available.

   To our surprise only a small amount of users commented about the drain of battery caused by most AR browsers ( "Tremendous drain on battery life. Actually causes my 3gs to heat up a lot", "But if it's gonna kill my battery, it has no place on my phone."), which we think originates in the fact that only a few people used AR browser for a longer time and consequently have experienced that sudden loss of battery power.

Beside these problems that were addressed in the comments many users also gave a good feedback that was often also justified with the fact that most AR browser are free to download. Many people also expressed their general interest as they identified the potential. We often read sentences saying that the current amount of content is small and there are still some bugs but that they will check back after some time as they think these applications have a huge potential. This supports also the comments of most people giving positive ratings as they often commented about the novel interface and how interesting it is but only a very small number commented on how they made real use of AR browsers.

## 4.3 Discussion

Overall the data from the distribution platforms show that the existing AR browsers perform similarly in term of user ratings. It also shows that there are no strong indicators for country specific or cultural specific effects in respect to the ratings. While the total number of ratings indicate that a large number of users at least tried AR browsers once, the real number of permanent users is still hard to estimate. Especially as the ratings suggest that the users opinions are quite different; many gave a low score - and it is likely that they stopped using AR browser - while another large group gave a high score. However, it suggests that there is likely a novelty effect affecting the high score of the second group. The comments also raised issues regarding the usefulness of the application, which brings the questions of long term use of AR browsers.

The comments from the Apple App Store show that the stability of ARB is one of the major issue that should be solved with a better software quality management. Further problems are caused by the low availability of content and the quality of the implemented interface. Solving all these issues would resolve 75% of the user complaints. A smaller group of users also pointed out problems in regard to content visualization and the rapid battery drain. This should not be underestimated, especially as the amount and density of the content will increase dramatically in the future and end-users may use more permanently of AR browser, these problems may become a major issue.

# 5 Conclusion

This technical report presented a first analysis of the adoption of Augmented Reality browsers by the public. Using two different evaluation tools - an online survey and an analysis on mobile distribution platforms - we reported on usage frequency, application scenarios, media consumed, subjective rating and general user comments.

During this analysis we identified similar patterns as an outcome of both tools, mainly with a population sample of technology enthusiasts. Firstly, a significant number of people tried AR browsers on their personal mobile devices and mostly noted positively the technology; they also pointed out their interest in this type of application. Secondly, the used tracking technology - GPS for position, accelerometers and compass for orientation - was not as a limiting factor as we expected, especially concerning the feedback from the mobile distribution platforms. Thirdly, participants and end-users confirmed the high potential of this technology in the future, especially regarding some application areas such as content browsing and navigation.

Some of the major issues, shown both in the survey and the mobile distribution platforms, were the scarcity of today's content on these platforms, the poor quality of the user interface (and user experience), and issues with battery life or the performances (probably due to the tremendous energy consumption of the variety of sensors involved in a standard AR application). From the analysis of the distribution platform, comments indicated the lack of reliability and robustness of Augmented Reality browsers, which is also a common issues for other mobile application.

In the future we aim to conduct further user studies, with a larger sample of participants and for long term usage pattern. We want to specifically address real scenarios and identify more accurately actual users of this type of application (in term of tasks, application areas, or advantages over location-based solutions). Additionally, social aspects specific to AR browsers will be investigated. As tracking technology rapidly evolves in Augmented Reality, we will also consider this factor and how this study remains valid with the integration of new localization algorithms and techniques (i.e. model-based tracking, SLAM, depth-based sensors) in Augmented Reality browsers.

# 6 Acknowledgements

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