Application Diversity in Open Display Networks

Constantin Taivan, Rui José
Centro Algoritmi
Campus de Azurém
4800-058 Guimarães, Portugal
+351253510319

{constantin,rui}@dsi.uminho.pt

ABSTRACT

We envision that future public display networks will be more interactive and open to applications from third parties similar to what we already have with smartphones. This paper investigates the application landscape for interactive public displays aiming to understand what would be the design and usage space for this type of applications. In particular, we explore people's perceptions and expectations regarding the diversity of applications that may emerge in future application ecosystems for public displays. We have devised a research methodology anchored on what is currently the rich and diverse range of applications in the mobile application market. We used a set of 75 mobile applications from Google Play application store and asked 72 participants about their relevance for public displays. The results showed that people had a clear preference for applications that disseminate content, and also that these preferences are affected by the type of location where the displays are deployed. These insights improve the understanding of the variables that may affect diversity in future display application ecosystems and inform the development of potential app stores in this context.

Categories and Subject Descriptors

H.5 [Information Interfaces and Presentation]: Miscellaneous

General Terms

Design, Experimentation, Human Factors

Keywords

Public Displays, Display Applications, App Store.

1. INTRODUCTION

Public displays are evolving from single-purpose information broadcasting artifacts into rich-interactive systems that are able to support a wide range of activities. This transformation requires substantial innovation and a new vision for Open Display Networks in which pervasive public displays and associated sensors are open to applications and content from many sources [8]. A fundamental step in that direction will be the emergence of

third-party applications, empowering developers to create applications that can be distributed and deployed across networks of public displays. Multiple entities anywhere in a global network could become co-creators of value by developing new applications. New ideas could quickly be shared and feed the innovation cycle. This role of displays as a new execution environment for applications is already being explored by some display infrastructures that anchor a significant part of their value proposition in the ability to select from multiple application alternatives [11][17].

An obvious parallel can be established between the currently closed model of public displays and what was once the closed model in mobile phones early before the emergence of the iPhone and Android eco-systems. Their mobile app stores have spurred the emergence of a huge diversity of application offers, transforming those devices from single-purpose communication artifacts into dynamic tools that are nowadays analogous to a "Swiss Army Knife" [18] with an excess of readily-accessible functionalities for everyday life, e.g., navigation, sports, playing games, listening to music and sightseeing.

Building on the parallel with mobile app stores, application diversity is often presented as one key motivation for a similar model in display applications. While we can easily acknowledge the overall potential of the approach, we cannot base our entire expectations on what is today the success and the characteristics of mobile app stores, as there are significant differences between the mobile devices eco-system and that of public displays. Mobile applications are designed for specific and personal devices owned and used by a single person. Display applications target a shared environment, where they can impact multiple stakeholders, from display viewers to venue (display) owners and to content or applications creators. One possible implication, for example, is that common expectations regarding the range of available apps may become more important than a huge diversity in which each display is entirely different in its application set than all the others.

In this study, we seek to uncover existing perceptions and expectations in regard to the broad range of potential applications that may emerge in future application stores for public displays. Our goal is to inform the development of these app stores by providing a better understanding of the variables that may affect diversity in future display application ecosystems. We have identified a large and diverse set of potential displays applications and we ran a questionnaire with 72 participants where we asked people about their view of value proposition of those applications. The results showed that people had a clear preference for applications that disseminate content, and also that these preferences are affected by the type of location where the displays are deployed.

2. RELATED WORK

Early research in public display has been concentrated around single-concept or single-application systems (e.g., [4]). Recently, an increasing body of research addresses multi-application installations in which displays offer passers-by a broad range of possibilities. With such displays, people experience a large number of applications and displays become an execution environment for dozens of interactive applications [17]. This raises a number of new research challenges that include technological issues, such as exploring the limitations and opportunities of web technologies for creating display applications [20] or understanding the extent to which application location impacts user experience when appropriating displays [7]. Cardoso et al. [3] studied interaction abstractions for public display that allow developers to hide the complexity of managing various interaction techniques in order to provide display applications with interactive features.

Sarah et al. [6] addressed the case of an application store as a distribution platform for public display applications. Conceiving such application stores faces specific challenges when compared with the mobile counterparts, such as dealing with multiple stakeholders, new business models and scheduling requirements. Other works include the challenges to present, organize and promote applications. Hosio et al. [10] studied the effects of application discoverability on the adoption and potential success of applications. Elhart et al. [9] investigated the scheduling mechanisms of integrating interactive applications with digital signage and Taivan et al. [21] studied the techniques to allow people to control applications in a public display.

A number of display infrastructures have already explored the concept of multi-applications displays. The Oulu display network [17] supports a broad range of applications, more specifically, by April 2012 the system included 25 distinct applications in seven categories: News (3), Services (3), City (3), Third Party (4), Fun & Games (5), Multimedia (3), and New Cool Stuff (four apps developed within the 1st International UBI Challenge). Many of these applications are interactive, taking advantage of the touch-sensitive displays or the Bluetooth, RFID or Camera capabilities. Instant Places [11] is a display-centric platform for media sharing that handles sensing and interaction information associated with places where the displays are located and provides an integrated API from which subscribed applications can obtain information about the current circumstances around the display in which they are being used. A diverse range of web-based display apps have been created as part of the Instant Places deployments, generating new insights on how a global application may generate situated information on each of the displays where it is used.

Previous work has also studied people's expectations in regard to content on public displays. While certain studies only asked people about content preferences [16][14], others explored practices on content creation and consumption [5]. Muller et al. [16] studied user expectations and its impact upon the attention users give to displays. The authors found that people attend displays when they expect interesting content including local news, events and information, sports and entertainment and usually ignore displays that show only advertisements because they are not interested in. Memarovic et al. [14] showed how public displays are part of a communicative ecology in which they're mainly associated with content that addresses a student community and its interests. Sarah et al. [5] provided insights into a long-term (over 3 years) and everyday usage of an university experimental digital signage system from the point of view of type of content (images, web pages, videos and streams) and its purpose, the content providers and display owners.

We aim to extend this work on people's expectations and preferences by trying to uncover some of the limits of application diversity in future scenarios where broad availability of third-party applications could offer people the opportunity to select potentially any content they would like to see in public displays.

3. RESEARCH DESIGN

A key challenge for this research was the current lack of any established systems where display apps are already being created and used in everyday life. The prevailing model in current Digital Signage networks does not consider applications, and research efforts have typically focused only on specific parts of the problem domain. This means in the first place that we do not yet have any real display application ecosystem from which to obtain data about application diversity. It also means that we cannot expect people to be able to envision the range of display applications that they are likely to have in the future.

To mitigate these challenges, we have devised a research methodology anchored on what is currently the rich and diverse range of application in the mobile application market. Even though there are multiple differences between both systems, the mobile app stores provide an extremely diversified set of applications that are already part of people's lives and therefore an excellent sample to consider display-based versions of the same applications. By challenging people to think beyond the most common and obvious examples of display applications and consider scenarios that they would otherwise never envision, this approach has allowed us to significantly broaden the range of applications being considered in this study.

The experiment involved the creation of a representative application set and a questionnaire about the envisioned value of having those applications available on public displays. In order to study the application diversity for public displays we identified two dimensions: (1) the range of application categories seen as relevant for public display usage and (2) the set of application categories associated with different types of places.

3.1 Application Selection

The initial step was the selection of a representative sample of display applications. We used Google Play application store[1] as our source of applications. For creating a representative set of applications for our study, we selected applications from the whole range of application categories in the Play Store. However, the number of applications in each category was not uniform. Instead, we used data on mobile applications usage [1] to select from each category a number of applications proportional to the total number of applications in the same category. We came out with three levels of categories.

The first level involved those categories with more than 500 distinct applications, i.e., *Books & Reference, Business, Comics, Communication, Lifestyle, News & Magazines, Productivity, Social, Tools, Travel & Local*; in this level we chose 5 applications per category (50 in total). The second level involved categories with more than 100 distinct applications, i.e., *Health, Finance, Sports, Shopping, Multimedia*; in this level we chose 3

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[1] There was not any specific reason to choose Google Play store.

applications per category (15 in total). The third level involved categories with fewer than 100 distinct applications, i.e., *Education, Entertainment, Transportation, Medical, Weather*; in this level we chose 2 applications per category (10 in total).

To maximize the diversity of applications, we selected within each category, applications that were as diverse as possible. For example, in the case of *Book & Reference* category, we selected apps ranging from dictionaries and information sharing to software for reading e-books. In the end, the selection process identified a set of 75 applications.

3.2 Application Categories

The second step was the categorization of the applications. The goal was not to envision what future application categories for display applications might be, as real display applications categories will evolve based on the dynamics of application usage over time. The goal was to provide a frame of reference to support the analysis of the results. For this, we considered two different types of categorization.

The first categorization was to simply use the categories of the Play store itself. These were already associated with the applications and their analysis provides an interesting path for comparing the diversity in mobile app stores with the potential diversity of public display applications. Since there was a disparity between current Play Store categories and those described in the study by Böhmer et al. [1] that we used for app selection, the Play Store categories Media&Video, Music&Audio, Photography were merged into a single one called Multimedia. The categories of Games, Widgets, Libraries&Demos, Personalization, Live Wallpaper were not considered because most of the applications in those categories were mainly aimed at specific features of mobile devices.

The second categorization was specific to public displays applications. For this, we analyzed the literature on display applications in search for different classification dimensions for those applications. To minimize the potential subjectivity involved in classifying applications that do not exist yet, we have only selected very high-level classifications and we have explicitly defined any additional assumptions that were needed to resolve ambiguities. The result was a set of 6 application categories, described next, that represent the main combinations of different categorizations from the literature. We then classified our sample of 75 applications according to these categories.

1. **Personal (11 apps).** This category includes applications that are based on content that is to some extent private as identified in [15]. Such applications are traditionally perceived as more appropriate for an individual usage. The content or services these applications provide can only be accessed by its owner and is less suited for public broadcasting e.g., *Private Diary*, *File Manager*.

2. **Informative (21 apps).** This category includes applications whose primary aim is to disseminate information through public displays, regardless of the specific type of content, as described in [17]. Content provided by this type of application can be presented in public circumstances where there is more than one person attending a display e.g., *IKEA Catalogue, Wikipedia*.

3. **Situated (8 apps).** This category includes applications that address the display context. We followed the description from [12] where the authors make a distinction between content that is static, i.e. does not consider the display context and content that is dynamically assembled for each particular display. This is where we included all types of location-based applications, e.g., *Where are you sweetie*, *GPS Navigation and Maps*.

4. **User Generated Content (4 apps).** This category includes applications whose primary aim is to support the publication of user-generated content, according to some particular publication paradigm [11]. This is where we included most social media applications, e.g., *Facebook*, *Instagram*.

5. **Interactive Experiences (18 apps).** This category is based on [17] where the authors describe that functionality, not information type, defines a display. It includes applications that involve rich user interactions leading to an engaging, and possibly playful experience where one is totally absorbed by the interaction. The goals of these applications vary from diverse communication practices, e.g., *Skype*, *Azores Cam 2*, to entertainment and artistic scenarios, e.g., *Real Piano*, *Fun Face Changer*.

6. **Other (13 apps).** This category includes applications that do not fit into the other categories, mostly because they do not have a specific type of content that could be shown on the display. They are rather seen as tools for specific goals, e.g. *Smart Compass*, *QR Code*.

3.3 Application Distribution among Places

Another dimension of application diversity is the extent to which different types of places may suggest different sets of application categories. We would like to identify particular applications or application categories that may be seen as universally relevant or places that stand out in terms of their unique application set. This would be an important hint for managing user expectations in regard to each new public display that they may find.

We defined a set of 8 types of places: **Parks:** city parks, children's playgrounds; **Shopping:** Malls, Hypermarkets; **Transport:** Airports, railway stations, bus/metro stations; **Squares**: Cities' square, Plazas; **Shop Windows***:* Shop Window in Streets; **Bars:** Cafés and Bars; **Sports:** *S*kate parks, Football or Basketball Stadiums; and **Corporate:** Public and Private Institutions. Despite the potentially substantial differences between these places, we did not consider any potential limitations imposed by different types of display capabilities, e.g., touch or gesture interaction or display position, e.g., direct reach.

3.4 Experimental Procedures

To collect data regarding peoples' perception of the value associated with the applications in our sample, we created a mockup of a display app store populated with the 75 applications from our sample[2]. They were described by title, a small application image and a short description as found in the Play store. The goal was to ask participants to use the mockup app store and select the applications they consider relevant for public displays. To manage the effort needed to answer the questionnaire, each participant was only shown 15 of the 75 applications. To guarantee an adequate distribution of the various application categories, we created 10 different combinations of 15 applications, each to be shown to each participant.

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[2] http://www.bioma.ro/appdiversity/welcome.html?lang=en (Last accessed: 25.04.2014)

The procedure involved two consecutive steps. In the first step, we presented participants with 15 applications (a random group from 10) in a random order and asked them to indicate the relevance of each application in public displays using a 5 point Likert scale (1 – Not relevant, 2 – Slightly relevant, 3 – Not sure, 4 – Relevant, 5 – Strongly relevant). Applications were shown without any indication about their category. In the second step, participants were asked to associate each of those applications to the type of place, from our list of 8, that they considered to be appropriate for a particular application. Participants could associate each app with more than one place.

The questionnaire was announced on several internal mailing lists at our University and also through flyers distributed at two university bars. During the one month period in which the questionnaire was open, we received answers from 72 different participants, mainly students, researchers and professors (most of them had background in computer science). An answer from one participant corresponds to the assessment of 15 distinct applications and overall, we had 1080 applications assessments. On average, each application was assessed 14.4 times, with every application being assessed at least 12 times.

3.5 Results and Discussions
In this section, we analyze the results according to each of the categories and also to the association to places.

3.5.1 Mobile Application Categories
The first line of our analysis is the relevance associated with the categories from the mobile app store, as represented in Figure 1.
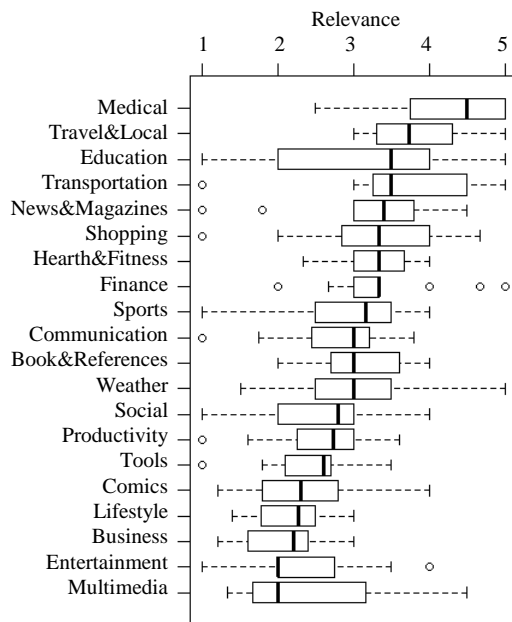

Figure 1. Application relevance by app store categories

For this analysis, we aggregated the answers for each application category and calculated an average score. While the results for each individual category may raise interesting interpretation questions, the lack of qualitative data about the options made by participants do not allows us to take many conclusions on particular order of the categories. We can however point that the most relevant one, *Medical* category, was actually composed of only two applications, both associated with emergency situations: *In case of emergency app* (location based listing for hospitals and

doctors, SOS message) and *First Aid* app (First Aid is designed to help people follow the right procedures in a stressful situation). This seems to be aligned with previous work that considered the potentially strong role that public displays could have in emergency situations [8].

Similarly, the *Multimedia* category, was only composed of three applications, i.e., *Real Piano* (play piano), *Customizable Gallery 3D* (make 3D photo galleries), *Diptic* (tell a story by combining multiple photos to create a photo collage). The low rank of these creativity-oriented applications may suggest that people perceive the role of public displays as being mainly informative, and would probably not feel comfortable in exploring the entertainment and playful side of public display installations or expressing themselves through a medium that they do not yet fully understand. This would be in line with previous results on people's expectations of content by Muller et al. [16] and is also coherent with the observation that almost all categories in the top of the diagram are mainly about informative content. However, it may represent a key challenge for the many types of interactive display applications (e.g., [13]) that are increasingly deployed in urban environments, as people may not yet be prepared to understand the full potential of public displays as a highly interactive and public multimedia tool.

3.5.2 Public Display Application Categories
The second line of our analysis is the relevance associated with the categories from the display application categories, as represented in Figure 2.
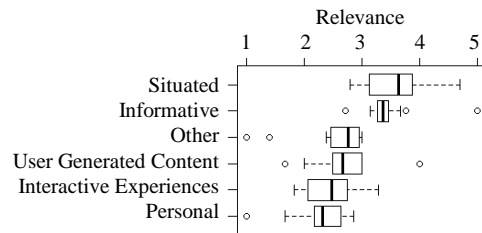

Figure 2. Application relevance by public display application categories

When we consider these categories the preference for applications focused on informative content seems to become much clearer. However, applications with the ability to offer situated content should to be favored in regard to applications that merely distribute static content. This seems to confirm that situated content that is dynamically assembled at each public display is perceived as more relevant for public displays than their use as a mere replacement for traditional static digital displays [13]. A Kruskal Wallis test was applied for the first three categories: *Situated, Informative and Other* and it revealed a significant effect of categories on application relevance ($\chi^2(2)=26.05$, $p < 0.001$). A post-hoc test using Mann-Whitney tests with Bonferroni correction showed significant differences between *Situated* and *Other* ($p < 0.001$, $r = -0.75$) and between *Informative* and *Other* ($p < 0.001$, $r = 0.79$).

The relatively low ranking of applications for user-generated content may once again represent a huge challenge for the many display deployments that are now exploring the intersection between public displays and social media. Even though most people are now social media users, they do not seem to understand the possible role of public displays as an additional channel for the expression of their identity. Previous work on

sharing social media on public displays has also identified this problem. For example, Memarovic et al. [14] studied sharing practices of social media content and found that personal content, e.g. pictures from last night's clubbing, comments, personal photos or personal status updates is not desirable for publishing and viewing on public displays. Instead, people prefer to use Social Networking Services (SNS) to share this type of content. This also seems to confirm the need for new publication paradigms that enable people to publish on public displays while being in full control of the process itself and especially its social meaning [11].

Again, the low score of *Interactive Experiences* category seems to confirm the idea that people do not immediately perceive the creativity, playfulness or communication potential of public displays or at least may fear the "social awkwardness" that may still be associated with most such experiences [2].

3.5.3 Application Distribution among Places

The third line of our analysis is the association between applications and places. We conducted the analysis from the perspective of application categories (Table 1 - a) and from the perspective of places (Table 1 - b). To analyze the association between application categories and types of place, we first created a table with the scores of each category for each of the places. A score was how many times the applications from a particular category were selected for a specific place. We then converted the scores into percentage scores using the total number of application assessments within a category – value that shows the maximum number of selections that can be attributed for a place within a category. For instance, in the case of *Personal* category we had 171 assessments (resulted from 11 apps, one app being assessed in average of 15.54 times) and only 27 were for *Parks;* this gave us a percentage score of 15.79%. Next, using the percentage scores, we calculated the mean (M%), standard deviation (SD% not shown), the coefficient of variation (CV%). In the end, we aggregated the results based on the two perspectives. In the case of Table 1 – a, we show the results by category and in the case of Table 2 – b, the results were shown by places.

In the first perspective (Table 1-a) a category with a higher CV score is one that presents more significant differences in relation to the types of places where it is seen as appropriate. For instance, in the case of *Personal* category, the highest CV shows that people were much more sensitive to the types of place when considering the use of applications in this category. On the contrary, more generic applications, such as those focused on informative content, are seen as potentially relevant anywhere. This means that they are more likely to become part of the expectations people may have in regard to any public display they may find.

In the second perspective (Table 1 – b) a place with a higher CV score is one that presents more significant differences in relation to the type of applications that can be expected. For example, in the case of *Shop Windows* the highest CV shows that there is a stronger focus on specific application categories, while for *Bars* the lowest CV would potentially represent a place with a broader set of application categories.

Overall, these findings suggest that people's expectations in regard to the range of available applications change according to the characteristic of the place. This idea that different places call for different types of applications is in line with the long-term

insights from real-world display infrastructure [17][19] that clearly observed the importance and effects of the location upon the content and applications usage. One such effect described in [17] is that location might decrease interaction. The authors observed how a similar display deployed in a swimming hall and a business center generated much more interaction on the swimming center because people had more time to spend without being in hurry.

Table 1. Application distribution among places:
(a) by categories; (b) by places

Public Display Apps Categories	M	CV%	Most / Least Relevant Place
Personal	24.56	39.39	Corporate / Shop Windows
Interactive Experiences	26.35	31.48	Bars / Shop Windows
Situated	48.84	31.46	Transport / Corporate
User Generated Content	33.90	27.90	Bars / Sports
Informative	41.64	25.85	Transport / Corporate
Other	34.92	17	Shopping / Corporate
Most / Least Relevant Place(s) across Categories			**Transport, Bars / Corporate**

(a)

Places	M	CV%	Most / Least Relevant Category
Shop Windows	28.23	44.18	Situated / Personal
Parks	34.70	40.79	Situated / Personal
Squares	38.97	40.47	Situated / Personal
Sports	25.77	32.44	Situated / Personal
Transport	45.01	30.61	Situated / Interactive Experiences
Shopping	40.37	28.90	Situated / Personal
Corporate	26.46	26.80	Personal / Interactive Experiences
Bars	40.78	18.77	User Generated Content / Situated
Most / Least Relevant Category across Places			**Situated / Personal**

(b)

However, more importantly, these results also indicate that place types may not only influence the appropriateness of particular application categories, but also the range or diversity of application categories that could be found on public displays. This seems to suggest that in a scenario of plenty of application offers, there might be public displays with a more restricted usage and consequently a more restricted application set, e.g., *Shop Windows*, and other displays with a much broader usage scope and consequently also a potentially much broader set of available applications, e.g., *Bars*.

Again, these results consolidate the findings from the second line of analysis (public display application categories). While *Situated* applications were perceived more relevant for outdoor locations (the majority of places), *Informative* applications are more likely to be part of common expectation of any display. An interesting example is *Other* category which shows that people do perceive short task-based functionalities as universally relevant apps.

3.5.4 Limitations

A key limitation in this study is the way we relied on the ability of participants to envision how different types of mobile applications could be repurposed for the public display context. Being open in regard to how people perceived this adaptation was part of the methodology so that people would not be caught up in the details and could instead focus on the respective value propositions. However, we cannot fully account for the effect that these open interpretations may have had in people's answers and to what extent the results would have been different if participants had answered based on a frame of reference composed by known applications or new applications for which we could provide our own description.

4. CONCLUSIONS

In this paper we studied people's perceptions and expectations regarding the diversity of applications that may emerge in future application ecosystems for public displays. Open Display Networks constitute a new frontier for digital content and user expectations are going to affect the evolution of an application ecosystem in this area. Firstly, our study revealed that there are multiple types of functionalities or applications on which people would be interested in public circumstances ranging from dynamic and informative content to applications providing utilities for short task-based scenarios. It is not clear to what extent people would appropriate public displays for more personal and individual application usage given the fact that such experience might involve different privacy issues. Secondly, we observed that certain applications could be considered as core or universally relevant and should be available everywhere, while others are tightly connected to particular type of place. In our future work, we will try to uncover in more detail the set of applications that may correspond to what people may expect to find on most public displays, as well as other application aggregations that may correspond to specific display concepts.

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