Interactive Data Visualization for Second Screen Applications: State of the Art and Technical Challenges

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Abstract. While second screen scenarios - that is, simultaneously using a phone, tablet or laptop while watching TV or a recorded broadcast - are finding their ways into the homes of millions of people, our understanding of how to properly design them is still very limited. We envision this design space and investigate how interactive data visualization can be leveraged in a second screen context.
We concentrate on the state of the art in the affected areas of this topic and define technical challenges and opportunities which have to be solved for developing second screen applications including data visualization in the future.

Key words: Information visualization, second screen, multi screen, mobile device, touch

1 Introduction

With the continuous proliferation of accessible computational devices, the media consumption behavior of millions of people is significantly changing. While traditionally medial content was consumed with one device at a time, multi device setups become more and more common. One specific instance of a multi device setup are second screen (2^{nd} screen) scenarios in which a secondary device is used to access information while simultaneously watching television or a recorded broadcast on a large screen. While many studies show the rapid increase of 2^{nd} screen usage [26, 36, 37], dedicated applications for it are still in its infancy and very little is known on how to properly design them.

Often numbers, data and graphics are used in broadcasts. Because of limited time, editors have to reduce those data and cannot give an extended description of the content. Data visualization can help here to provide an easy to understand detailed description of the content [40]. Therefore, integrating interactive data visualization in a 2^{nd} screen application seems to be a promising approach.

Target devices for 2^{nd} screen applications are mainly laptop, smartphone and tablet [37]. Because of increasing sales figures for tablets and smartphones and decreasing sales figures for laptops, which are projected by the International Data Corporation (IDC) [20] until 2018, the focus in this research is on mobile touch devices like tablets and smartphones.

We will give an overview of the state of the art in the affected areas of developing 2^{nd} screen applications with visualization. This endeavor comprises related aspects from different disciplines in computer and media science. We therefore will take into account aspects not only from the still small research field on 2^{nd} screen applications, but also from a technical perspective (interactive visualization on mobile touch interfaces, multi device environments and their synchronization) and from a content perspective (TV formats). Afterwards we describe technical challenges which have to be solved to develop visualization for 2^{nd} screen applications as well as opportunities for such scenarios.

2 State of the Art

To provide a broad overview about the topic of 2^{nd} screen applications with visualization we investigate the following areas: (2.1) Interactive TV & 2^{nd} Screen, (2.2) TV Formats for 2^{nd} Screen Scenarios, (2.3) Visualization on Touch Screens, (2.4) Multi Screen Environments and (2.5) Device Synchronization.

2.1 Interactive TV & 2^{nd} Screen

Since smartphones and tablets have appeared on the market, the behavior of watching TV has changed [11]. Obrist et al. [29] emphasize that: *"Television still plays an important role in everyday life, but the way we consume and interact with TV content has changed dramatically."* A survey by ARD/ZDF (German public-service broadcasters) [6] found that 56.6% of TV users also access online content via 2^{nd} screen devices simultaneously to the TV, supporting the statement of Proulx and Shepatin [32] that *"The internet didn't kill TV! It has become its best friend"*.

With the proliferation of such 2^{nd} screen scenarios, research in the field of TV is now increasingly focusing on human-computer interaction in the sense of developing new interaction concepts for domestic environments [17]. However, one of the major challenges is that the audience switches attention between a TV and one or multiple mobile devices. The recent experience of watching TV is far beyond the 'lean back and do nothing' ethos from the past, but it's challenging to heel the audience to action. The recent trend is not to create an alternative to watching TV, which might distract the users from TV's content, but to support the users' immersion and the program's enhancement by using additional information about the content of the TV broadcast and about user-generated content through back channel solutions [12]. While 2^{nd} screen applications clearly open up a whole new space of possibilities, they are still

heavily underutilized [11]. Although broadcasters recognized the potential and have started to provide dedicated 2^{nd} screen applications, the knowledge about what works is still limited [16]. Based on an analysis of Twitter messages during a live broadcast, Lochrie and Coulton [24] found out that smartphones are heavily used as 2^{nd} screens, but that the audience mostly create their own forums for inter-audience interaction using (social media) platforms such as Twitter or Facebook that are disconnected from the primary content channel.

Bubble-TV (see Figure 1) is one of the few existing examples of an innovative solution that embeds Twitter feeds as dynamic visualization in the background of a TV studio during live discussions [18]. Bubble-TV goes far beyond showing single tweets as the audience makes decisions and can intervene immediately at several points of the show.

Fig. 1: Bubble-TV: Dynamic visualization in the back of a TV stage [18].

In their survey 'In Front of and Behind the Second Screen', Geerts et al. [16] defined five critical success factors of a 2^{nd} screen application: ease of use, timing or live synchronization, social interaction, attention and added value. In addition, Obrist et al. [29] came up with the four key areas of research in interactive television: content, recommendations, device ecosystems and user feedback.

2.2 TV Formats for 2^{nd} Screen Scenarios

Interaction and the supply of information via several channels are key components for successful future television. There is a wide range of usage possibilities of these features depending on the format and topic of the content [6]. In a survey conducted at St. Pölten University of Applied Sciences [38], annual data about the state of the art usage of 2^{nd} screen applications in the field of information television was investigated. The results showed that there are five layers of interaction in TV programs that reflect how intense additional applications can be used to enrich a broadcasted show: (1) *social media platforms* offer a space to share opinions and discuss the TV broadcast independently in

real-time; (2) *moderated social media* where the broadcaster is part of the social media content production; (3) *responded social web activities* where viewers can intervene/influence first screen (1^{st} screen) content via back channels; (4) *cross media storytelling* where the user has several options to follow the story and multiple platforms offer additional content and information; (5) *user-generated content* where users themselves are contributing material.

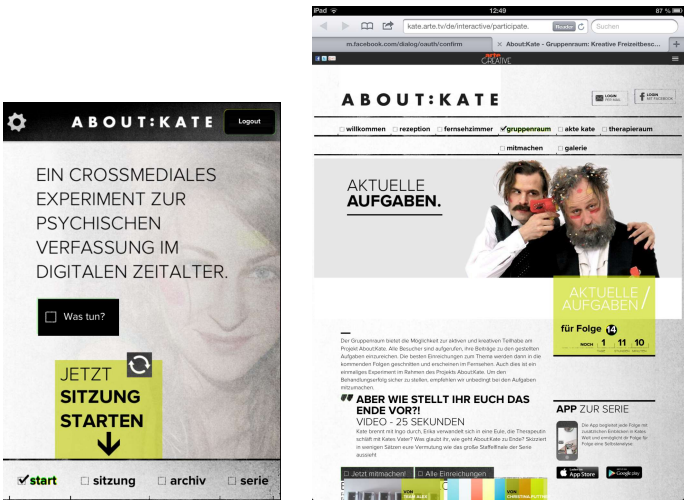
Fig. 2: 2^{nd} screen application published by the Austrian public broadcaster ORF for the skiing world championship 2013[1].

Following the half year report of Goldmedia Custom Research's TV Monitor [1] the late night show 'Circus Halligalli' counts the most web and social media activities on the German TV market. Big sports events and in general all kinds of live events achieve a high level of interaction on social media platforms. During the skiing world championship 2013 in Schladming, the Austrian public broadcaster ORF offered a successful 2^{nd} screen application (see Figure 2). The user was able to switch between several additional camera angles, an instant live standing was available and background stories were offered. Further a strong social media support was provided[2].

According to Würbel et al. [43], the creation of a nonlinear multi stream video show in real-time, which changes to the interests of the consumer instantly, is the future of interactive TV. They have tested such a concept with 489 users during the Olympic games in Beijing in 2008. During this test, explicit and implicit feedback has been collected and analyzed to adapt the program to the audience's needs.

Apart from these examples for specific events, there are a number of notable examples of TV formats that offer innovative solutions of integrating 2^{nd} screen applications. 'About:Kate'[3] for instance, is an innovative TV series, produced by ulmen.tv on behalf of ZDF/ARTE. This series is state of the art in the field of cross media storytelling with the usage of different 2^{nd} screen applications like a smartphone app and a web platform to upload user-generated video clips

[1] `http://bit.ly/1i92xFa`, accessed September, 2015.
[2] `http://bit.ly/1i92xFa`, accessed January, 2015.
[3] `http://bit.ly/1iod8wH`, accessed December, 2014.



(a) Home screen of the smartphone app where you can start the session.

(b) Home screen of the website opened on an iPad.

Fig. 3: Cross media storytelling for the TV series 'About:Kate'.

related to the narrative of the TV series[4] (see Figure 3). The production company created a virtual character called Kate that users follow via TV and different social media platforms. Users can watch Kate's blog and, via the smartphone application, Kate will randomly call them during the live broadcast.

Another example for 2^{nd} screen applications is the 'Red Bull Signature Series' that Red Bull produces in collaboration with Shazam and the US TV station NBC[5]. This format includes a snowboard live broadcast and a 2^{nd} screen application. The user can watch the sport event from another point of view, for instance the ego perspective of the world's most progressive riders, synced to the live image of the TV set. The synchronization is performed via the audio signal of the TV broadcast. Shazam also connects automatically to social media platforms. The viewer is able to follow all the riders and the event organization during the event[6].

While these are all innovative concepts, there is still a wide space of opportunities that has not been explored so far. Most of the existing work was developed and approved for narrative content, sport events and game shows because these are entertaining events with a high level of community response. However, in the segments of TV magazines, documentaries and live broadcasts the challenge is to visualize and distribute more complex data sets synchronized to the live broadcast on 2^{nd} screen applications. Moreover, there has been very little focus on

[4] `http://bit.ly/1J655cQ`, accessed January, 2015.
[5] `http://bit.ly/1i92Y2g`, accessed January 2015.
[6] `https://www.youtube.com/watch?v=7ftyEUIYcJ8`, accessed January 2015.

representations of the content that can be adapted to the preferences and needs of different viewers, for example via personalization or location-aware features.

Another interesting aspect is the differentiation between traditional TV broadcasting and recorded content as well as online video. Taking into account other viewing habits (e.g., watching a whole season at once) the type of secondary content differs. In this case the 2^{nd} screen application could contain the content for the whole season and not only for one episode.

2.3 Visualization on Touch Screens

Visualization is as much of importance for the informed citizen as it is for expert users. For a long time, expert users have been the main target group in visualization research. Only recently, interest in broader audiences grew by activities in the areas of *visualization for the masses* [44], *casual information visualization* (e.g., ManyEyes[7], Tableau Public[8]) or *data journalism* [7]. Both, Al Gore's Nobel prize-winning campaign on global warming and Hans Rosling's work on sustainable global development[9] demonstrate how visualization can be successfully applied to educate broad audiences. However, utilization of data visualization in regular TV formats is relatively uncommon apart from classical infographics and maps in news broadcasts with relatively low information density. Moreover, the mentioned examples are incorporated for storytelling in 1^{st} screen contexts that are fully controlled by the broadcaster and keep the viewer in a passive role. During the last years, natural user interfaces (NUIs) have become increasingly relevant for visualization [34, 23]. Pike et al. [30] point out the need for better understanding and novel forms of interaction via a so-called 'science of interaction'. Along these lines, Elmqvist et al. [15] demand the concept of fluid interfaces that lets users touch and manipulate elements directly instead of interacting indirectly with interface widgets, which can be seen as extension to the concept of direct manipulation introduced with the advent of graphical user interfaces (GUIs) in desktop operating systems [19].

However, the context of mobile devices introduces a diverse set of challenges and opportunities for visualization. For example, Chittaro [10] summarized that *"[...] visualization applications developed for desktop computers do not scale well to mobile devices"*. PRISMA Mobile is an Android-based information visualization tool for tablets with treemaps, zoom (with pinch gesture), filters and details-on-demand [13]. The mobile tourism information analysis tool by Pinheiro et al. [31] is JavaME based and shows hierarchical data as treemaps, georeferenced maps and filters.

There is also some first research about using touch gestures in data visualization on mobile devices. Baur et al. [5] presented TouchWave (touchable stacked graphs, see Figure 4) with kinetic manipulations and integrated interaction without complex gestures. Drucker et al. [14] compared a non-touch-centric WIMP

[7] `http://www.ibm.com/software/analytics/manyeyes/`, accessed January, 2015.
[8] `http://public.tableausoftware.com`, accessed January, 2015.
[9] `http://www.gapminder.org/world/`, accessed January, 2015.

(window, icon, menus and pointer) interface and a touch-centric fluid interface on a tablet in a user test with 17 participants and showed that users prefer the fluid interface. Willett et al. [42] investigated user-elicited selection gestures on a non-mobile device (32" multi touch display). They found a strong preference for simple one-hand gestures, which is also relevant for implementing data visualization in 2^{nd} screen applications.

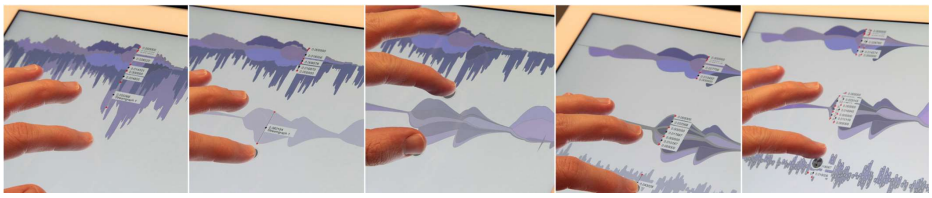


Fig. 4: TouchWave: Visualization for hierarchical stacked graphs [5].

Isenberg and Isenberg [21] published a survey on visualization on interactive surfaces. They have systematically analyzed 100 interactive systems and tools for small and big displays. The overview shows that most research work is done on multi touch tabletop devices. Smartphones are only used in 6% of the analyzed research projects although smartphones are disseminated widely. What's more, none of them is related to 2^{nd} screen applications.

2.4 Multi Screen Environments

In a 2^{nd} screen scenario, content is shared over two spatially disconnected displays. We are therefore facing a specific form of a multi display environment (MDE) with a 2^{nd} screen device and a bigger screen (e.g., TV or computer). Stemming from the different intrinsic characteristics of devices and the need to switch attention between them, MDEs pose unique challenges to the design of interactive interfaces [28].

While there has been much work in the human-computer interaction (HCI) and the computer supported cooperative work (CSCW) communities to better understand these design characteristics, there is only little work on how data visualization works in such environments. One of the few projects that intrinsically focused on visualization in MDEs is WeSpace [41] where users could bring their own laptops and share visual content on a larger screen. A similar approach was followed by Sedlmair et al. [35] when studying visual MDE applications in the automotive industry. In addition a smart view management concept for smart meeting rooms was developed by Radloff et al. [33]. This approach combines and displays views of different systems considering the dynamic user positions, the view directions as well as the semantics of views to be shown. Recently, Badam et al. [2] suggested a middleware framework for implementing visualization applications in such MDE environments.

Research in MDEs with visualization and 2^{nd} screen applications is still in its infancy. An important aspect seems to be linking and brushing across distant displays to get the users attention on the right screen for the right time.

2.5 Device Synchronization

2^{nd} screen applications require a robust device synchronization of all participating devices to manage the interactive visualization of additional content. A number of techniques have been developed so far: (1) manual sync, (2) time code sync, (3) direct link, (4) closed captions, (5) visual sync and (6) audio sync.

In (1) manual synchronization a visible (or audible) trigger is embedded into the broadcasted content and the user needs to actively push a button or select a position on a timeline to sync [4]. While this technique is easy to implement, it cannot maintain synchronization when the stream is paused.

Alternatively, (2) time codes can be used or devices can be (3) linked directly, e.g., using WIFI or a web server [27, 25]. However, these techniques require special hardware, which limits the broad applicability in different scenarios.

Another source of information for sync are (4) closed captions but a lot of content does not provide those.

(5) Visual sync triggers (QR-Codes as well as natural features) can also be used for synchronizing 2^{nd} screen devices which however is computationally expensive and heavily depends on the lighting situation. Ultimately, the audio channel provides robust features for synchronization.

Two general approaches in (6) audio-based synchronization are watermarking and fingerprinting. In watermarking, a time code for synchronization as well as data for the 2^{nd} screen (e.g. a URL) are embedded into the audio signal in a way that it cannot be perceived by humans but can be reconstructed robustly from the modified signal [22, 9]. This can be done completely at the client and the complete data is directly embedded into the primary stream. However, there are also a number of problems: the original content must be modified in advance (or at broadcasting time), licensing may prohibit watermarking for certain types of content and watermarks may become audible which is annoying for the user. In fingerprinting [39] a short audio snippet is recorded at the client, indexed, transformed into a compact signature and matched against pre-indexed content at the server with high accuracy. Fingerprinting does not change the content and is more flexible than watermarking but requires a pre- or real-time indexing of the broadcasted content. It has originally been developed for music identification [39] and has recently gained increasing attention for media synchronization in 2^{nd} screen applications due to its high precision and low latency [3, 8].

2.6 Summary

Studies confirm that smartphones and tablets are used as secondary devices whilst using the TV or computer [26, 36, 37]. However, these devices change the behavior of TV viewers. The synchronized usage opens up new possibilities (e.g., providing a 2^{nd} screen application with additional content related to

the specific broadcast). Currently, there are no generalized rules for designing 2^{nd} screen applications. TV stations and producers are searching for suitable concepts, testing applications in genres like narrative content, sport events and game shows. However, other segments like TV magazines, documentaries and live broadcasts provide an excellent basis for integrating visualization of more complex data sets to substantiate the content of the broadcast.

From a technical point of view, the topic of device synchronization is well covered in research. However, concerning visualization on smaller touch screens and MDEs more research has to be carried out. Interesting aspects are for example linking and brushing across distant displays and developing visualizations for different screen sizes and operating systems. In addition, current visualization research concentrates on expert users. With the integration of interactive data visualization in 2^{nd} screen applications the target audience will become more general and diverse.

3 Technical Challenges & Opportunities

Based on the findings of the state of the art (see Section 2) we derive technical challenges and opportunities to come for data visualization in 2^{nd} screen applications.

- **Visualization for the masses:** To bring visualization to the general public, we have to think about visualizations that allow to explore the data in an intuitive and understandable way. Users should not have to learn the visualization.
- **Visualization and cross device compatibility:** In relation to the different devices which could be used for the data exploration, it will be necessary to use a framework which supports cross platform compilation. In addition, an automated (semantic) scaling for the presented visualization will be needed in relation to the big variety of device screen sizes.
- **Visualization and touch interaction:** There should be a generalized set of gestures which work for a wide range of commonly used visualization techniques. According to these techniques there is a second interesting issue depending on the different screen sizes and resolutions of the devices. For example a small device with high DPI number is more sensitive for gestures than the same device with lower DPI (e.g., lower DPI $\rightarrow$ bigger gesture; higher DPI $\rightarrow$ smaller gesture).
- **Linking and brushing across distant displays:** This aspect depends on studying and advancing the process of visual synchronization (e.g., linking and brushing) for heterogeneous displays with different types of content (broadcasted TV and interactive visualization).
- **Recording the 2^{nd} screen exploration:** In relation to the new possibilities of this upcoming technology, it will be very helpful to give the user the ability to record his/her exploration depending on the broadcast to reconstruct his/her newly gained insights. This can be very helpful for schools for example:

A teacher watches an interesting documentary and explores the data on the 2^{nd} screen device. With the record function, he/she gets the ability to show this record in the next lecture. A further idea could be a picture in picture feature for broadcast and recorded explorations.

– **Crowd sourced commenting:** Following the Polemic Tweet project[10], 2^{nd} screen applications can be used for crowd sourced commenting. By integrating such applications into a live broadcast as back channel, users can participate directly with the TV content (e.g., political discussions).

4 Conclusion

As we have shown, interactive visualization of data for and from 2^{nd} screen devices is a complex and multi-faceted endeavor that touches both, technological as well as content-related aspects. Recent technical developments allow for new perspectives on the TV of tomorrow and mobile devices such as smartphones and tablets with interactive surfaces are ubiquitous and already applied as 2^{nd} screen devices today. However, these approaches are not well integrated and are mostly constrained to pointing to supplementary information or social media platforms focusing on text, image and video material. Toward application of future visualization integrated in 2^{nd} screen applications we defined technical challenges and opportunities which are not solved yet.

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