Interactive Mobile Data Visualization for Second Screen

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ABSTRACT

Traditional medial content was consumed with one device at a time. With the increasing simultaneous usage of several different devices like smartphone, tablet, and connected TV new approaches for media consumption are conceivable. One specific instance is a Second Screen scenario where users complement information from unidirectional media broadcasts (i.e. TV) with additional facts from a secondary Internet connected source (e.g. smartphone or tablet). However Second Screen applications are still in its infancy and very little is known on how to properly design them. The focus in the thesis will be on the role of data visualizations and how it can be used in Second Screen application for both sides: for the viewer, allowing interactive access to additional, visual, and personalized information that is not included in the broadcast TV content; but also for the TV stations, in order to get richer data about their audience by providing a direct backchannel. By answering the research questions the complete process of designing and developing interactive data visualization in the context of Second Screen applications for mobile touch devices will be investigated. In addition to several state-of-the-art reports a tested framework, which includes all relevant parts of a Second Screen application (e.g. content creation, synchronization, different types of visualization), and guidelines for designing and developing mobile data visualization for Second Screen applications, which are synchronized with the broadcast, will be developed.

Keywords. Interactive Data Visualization, Mobile Device, Second Screen.

1 RESEARCH PROBLEM

Smartphone, tablet and connected TV have revolutionized the way we access the Internet. We not only use several different devices throughout the day, we increasingly use them simultaneously. In 2013 more than half of Germanys Internet users regularly used more than one device at the same time (United Internet Media and InteractiveMedia CCP GmbH, 2013; SevenOne Media, 2013). A survey, conducted by Microsoft in the US, Australia, Brazil, Canada, and the UK, found that 57% of the participants used multiscreen settings for investigative spider-webbing (Micorosft Advertising, 2013) the simultaneous, information- and discovery driven activity related to TV-broadcasted information. That type of multiscreen setting, where users complement information from unidirectional media broadcasts (i.e. TV) with additional facts from a secondary Internet connected source (e.g. smartphone or tablet) is the relevant scenario for the thesis. It is called Second Screen (2S).

Surveys show that 2S applications have relevance (United Internet Media and InteractiveMedia CCP GmbH, 2013; SevenOne Media, 2013; Micorosft Advertising, 2013). 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. Interactive data visualization can help here to provide an easy to understand detailed description of the content (Ward et al., 2010). Therefor, integrating data visualization in a 2S application seems to be a promising approach.

Target devices for 2S applications are mainly laptop, smartphone and tablet (United Internet Media and InteractiveMedia CCP GmbH, 2013). Because of increasing sales figures for tablets and smartphones and decreasing sales figures for laptops, which are projected by IDC (2014) until 2018, the focus in this research will be on mobile touch devices like tablet and smartphone.

There are several research activities on data visualization for mobile devices and a very limited number of projects for the usage of data visualization within a 2S application (see section 3). Those 2S projects are only documented technically but there is currently no systematical research.

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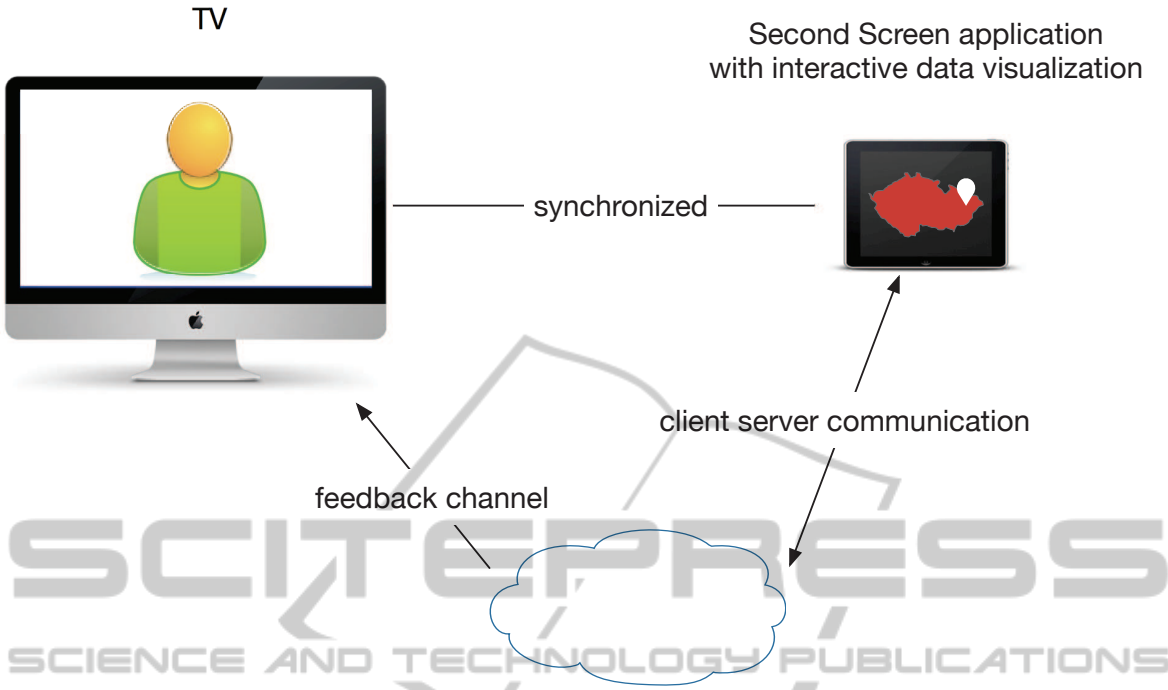

Figure 1: Overview of a Second Screen scenario.

Figure 1 shows an overview of a 2S application scenario. In a basic setting, a broadcast is running on a TV set. It could also be a laptop or a computer, where a recorded broadcast is on air. The 2S application with data visualization runs on tablet or smartphone and is synchronized with the TV (e.g. via audio synchronization). A 2S application communicates via the Internet with a server to receive and send data. The server could also provide a feedback channel to the TV station via the Internet. In doing so, broadcasters or producers could benefit by using 2S application e.g. for collecting user data or to integrate data in a live program.

In the following, two possible scenarios for integrating data visualization in a 2S application will be described:

1. A documentary on wildlife is called “Killer Whales - Fins of Change” (Wallis, 2014). It is about the movement of killer whales to northern regions. Data visualization within a 2S application can provide a map view where you can follow the killer whales to the Arctic. Interaction with the map could offer the user additional information e.g. geographical data about the affected countries as well as distribution and population of whales.
2. In a news program unemployment figures are a regular topic. Data visualization about unemployment figures could offer the user within a 2S application an easy to use overview about the count of the last years e.g. filterable by month, year and other relevant data. That visualization is reusable and will grow with every month it is used.

Major challenges of 2S settings that include interactive data visualization on mobile devices are:

- **User Interaction and Usability for Touch Input:** One of the main advantages but also problems of touch devices is the usage of fingers. The users cannot use their fingers in such an accurate way they would do with a mouse as the elements are smaller than the finger (fat finger problem) (Wigdor et al., 2007). In addition the fingers occlude the element itself while tapping on the element (occlusion problem) (Wigdor et al., 2007). Because of these facts, visualization should have an optimized user experience for touch usage.
- **Possibility for Synchronizing Visualization with Broadcasts:** An interesting part of 2S applications is the option of synchronizing the additional content with the broadcast. The visualization should show the relevant data synchronized to the broadcast. It is also a challenge for this study to find a way to synchronize the interactive visualization in a way that is visible but not distracting. A main problem is to get the users attention at the right time on the right screen (TV or tablet/ smartphone).

- **Additional Value for Broadcaster (or Producer) and User:** By interacting with visualizations, users are not only actively engaging with the exploration environment to gain insights for themselves, but also generating usage data that can be beneficial in other ways. First, such usage data could be an additional value for broadcasters (e.g. collecting data about usage) to influence a live broadcast for example. Second, other users could benefit from collective usage data for example by being pointed to interesting other parts of the visualization.

2 OUTLINE OF OBJECTIVES

The goal of this research is to study interactive data visualization methods on mobile touch devices in the context of 2S applications. This leads to the following main research question:

- How can interactive data visualization in the context of a Second Screen application be designed and developed for mobile touch devices?

To achieve this goal the following sub research questions will be answered:

2.1 Technical Questions

- Which touch gestures can be used for interacting with data visualization?
- Which types of data visualization can best be used for Second Screen applications related to scenarios, which are chosen?
- Which libraries and frameworks are most suited for developing interactive data visualization for mobile touch devices?
- How can a framework be created which includes all relevant parts of a Second Screen application (e.g. content creation, synchronization, different types of visualization)?

2.2 Conceptual Questions

- How should the interaction of the visualization be designed in order to be visible but not distracting if the app is synchronized with the unidirectional media broadcast?
- Which advantages and disadvantages do Second Screen applications have over traditional (unsynchronized) knowledge sources like Wikipedia or Google?
- How can content preparation process be supported in the context of 2S scenarios?
- How can guidelines for creating Second Screen applications with interactive data visualisation be drafted?

3 STATE OF THE ART

During the last four years Natural User Interfaces (NUIs) have become relevant for developing data visualizations (Reiterer, 2010; Kasik, 2011). Pike et al. (2009) also point out the need for improved options of interactions. Chittaro (2006) summarizes "[...] visualization applications developed for desktop computers do not scale well to mobile devices." Elmqvist et al. (2011) demand the concept of fluid interfaces. Fluid interface lets users touch and manipulate elements directly instead of interacting indirectly with the user interface.

Isenberg and Isenberg (2013) recently published a survey article for visualization on interactive surfaces. They have systematically analysed 100 interactive systems and tools for small and big displays. The overview shows that most research projects work with Multi Touch Table top devices. Smartphones are only used in 6% of the analysed research projects although smartphones are disseminated widely.

There are some relevant research projects of data visualization on mobile devices but not related to Second Screen applications. For example the visualization type treemap is used by the project PRISMA Mobile (de Jesus Nascimento da Silva Junior et al., 2012) and Pinheiro et al. (2008) on mobile devices. PRISMA Mobile is an android based information visualization tool for tablets (de Jesus Nascimento da Silva Junior et al., 2012). It also uses zoom (e.g. with pinch gesture), filters and details-on-demand. The tourism information analysis tool for mobile phones by Pinheiro et al. (2008) is a JavaME based tool, which shows hierarchical data. In addition to treemaps the tool uses georeferenced maps and filters. Paul et al. (2012) implement the visualization type Overview and Detail in their work. That project implements an Electronic Health Record (EHR), which shows medical reports and images on small displays of mobile devices. They use fragmentation algorithms to achieve their aim.

There is also some first research about using touch gestures in data visualization on mobile devices. Baur et al. (2012) presented TouchWave (touchable stacked graphs). They wanted to create a visualization, which has kinetic manipulations and integrated interaction without complex gestures. Two case studies were im-

plemented but no user tests were conducted. Drucker et al. (2013) compared a non touch-centric WIMP (window, icon, menus and pointer) interface and a touch-centric fluid interface on tablet through a user test with 17 participants. Results show users prefer the fluid interface. Touch gestures were not the main focus on that research but the survey shows that touch interfaces are relevant for tablet users.

Willett et al. (2014) did research about 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 important to know for implementing data visualization for mobile devices.

Regarding research activities with 2S applications, the 2S is used, for example, for giving additional information e.g. in the projects IntoNow (Castillo et al., 2013) and Story Map (Murray et al., 2012). Story Map includes data visualization. A character map of the current episode is shown. It is designed as a web app, which runs on two screens (a large browser-equipped screen and a smaller handheld device). The devices are time synchronized. So the character map can auto update the graph of all characters and relationships in real time. IntoNow (Castillo et al., 2013) uses the microphone of the Second Screen device to synchronize with the TV via audio-fingerprinting. If the fingerprint matches with a broadcast in the database, the application shows the name of the program as well as links to multiple online services.

Another facet is using the 2S for social interactions. FanFeeds (Basapur et al., 2012) and BubbleTV (Huron et al., 2013a) are examples here. FanFeeds allows authoring and consumption of secondary content around broadcasts. Users can generate secondary content for their own social circle. Tests of FanFeeds show that only a few persons are frequent content creators. The majority just consume "feed." Huron et al. (2013a) used in Bubble TV a live visualization of TV viewers' tweets that are integrated as a background for a French TV show. As a result of that project they introduced the new design metaphor Visual Sedimentation (Huron et al., 2013b).

Moreover, 2S approaches are often only described and not tested (Castillo et al., 2013; Murray et al., 2012). Classical user interface design for non touch devices follows the eight golden rules of interface design (Shneiderman and Plaisant, 2010). For designing visualization there is for example the Visual Information Seeking Mantra (Shneiderman, 1996). Additionally there are still no relevant findings for NUIs in data visualization (Lee et al., 2012). Because of that guidelines or best practices for interactive data visualizations in the context of Second Screen applications are currently not available (Lee et al., 2012).

4 METHODOLOGY

> *"Visual representations of objects are often misinterpreted, either because they do not match our perceptual system, or they were intended to be misinterpreted."* (Ward et al., 2010)

Therefore, visualizations have to be developed and tested in the context of specific tasks, users, and application domains (van Wijk, 2006; Munzner, 2009). To use visual methods effectively one has to plan professionally (e.g. with user and task analysis) and evaluate empirically (e.g. with usability testing) (Lam et al., 2012; Miksch and Aigner, 2014).

At the beginning, a desk research will be conducted, which includes extensive literature and web research. Topics like relevant data visualization types, touch gestures, data visualization libraries, and methods for synchronization will be researched, analysed, and evaluated to get a detailed state-of-the-art analyses. Evaluation is based on structured criteria.

To implement fully functional prototypes of 2S applications with interactive data visualization the study at hand uses the goal-oriented design process (Cooper et al., 2007) and experimental prototyping with user-centered design. It will be an iterative process. To decide which concrete scenarios will be developed, possible facets of usage for data visualization in 2S applications will be found as part of research. Two conceivable facets are

- offering additional information, and
- user integration (especially - but not exclusively - interesting for live broadcast to provide a feedback channel).

The actual number of implemented prototypes depends on found facets. Currently three tested prototypes are expected.

Concepts for visualization and interaction design will be evaluated based on mock-ups with qualitative user tests. Mock-ups will be improved by the results of the user tests and implemented as fully functional prototypes. To improve these prototypes usability tests will be conducted. Used methods will be eye tracking, audio-visual observation, and semi-structured interviews (Lazar et al., 2010).

At the end there will be a qualitative acceptance test to evaluate the prototypes and obtain information on the additional value of such applications. Ques-

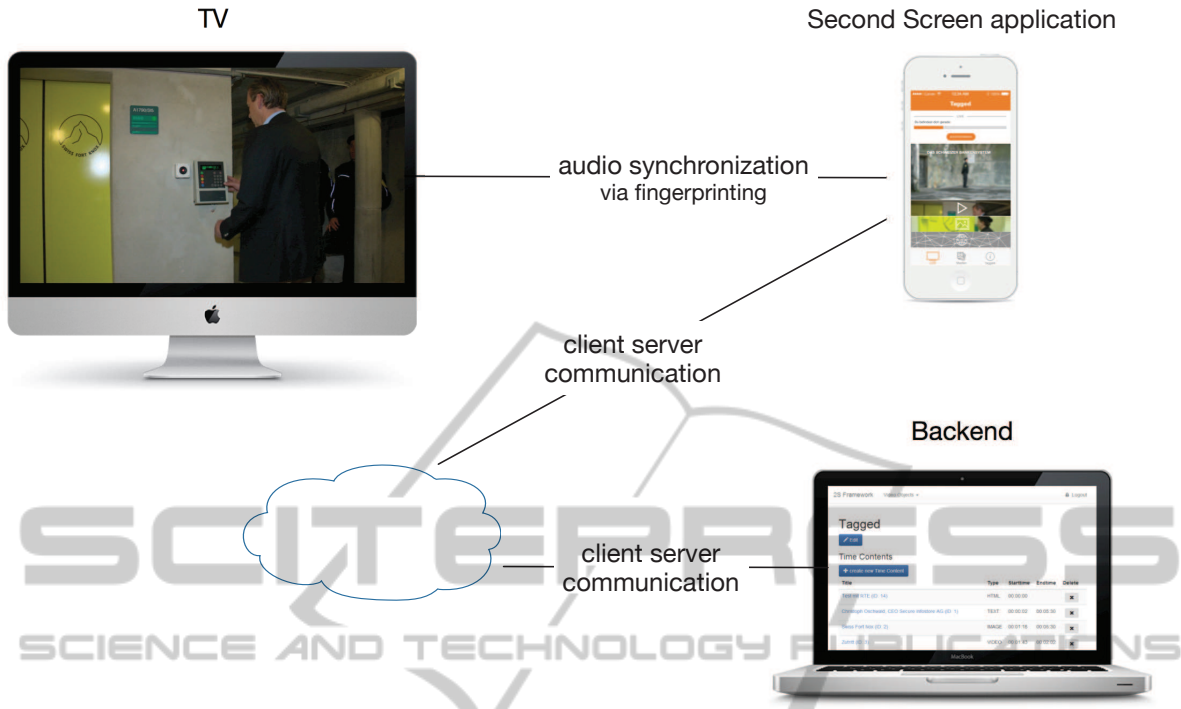

Figure 2: Overview of Second Screen Framework.

tions that need to be answered in that test are for example:

- Will the offer be understood, accepted, and used by the audience?
- How many steps of interaction can users handle while watching TV without being distracted?
- Will users be too distracted by 2S application?
- Which advantages and disadvantages do 2S applications have over traditional (unsynchronized) knowledge sources like Wikipedia or Google?

Tasks like finding the whale population in 2012 suitable for example in scenario 1 (see section 1) will help to find results for those questions.

Another interesting aspect concerns the preparatory work which is necessary for publishing a 2S application with data visualization. A concept will be developed and tested with experts of that field (e.g. broadcaster and producer).

5 EXPECTED OUTCOME

By answering the research questions (see section 2) the complete process of designing and developing interactive data visualization in the context of 2S applications for mobile touch devices will be investigated.

The systematic processing of existing work will be documented in detailed state-of-the-art reports for relevant data visualization types, touch gestures, visualization libraries and frameworks, as well as methods for synchronization.

Afterwards relevant data visualization types, visualization libraries and frameworks, as well as methods for synchronization will be evaluated and tested based on structured criteria. As a result evaluation reports will be created.

To reach the overall goal, an overview of facets for integrating data visualization in 2S application will be worked out. Building on that overview, concrete scenarios and concepts of data visualization for 2S applications have to be developed.

Furthermore mock-ups and fully functional prototypes of tested data visualization within 2S applications of three broadcast genres (e.g. politics, sciences, geographic) are expected. In addition to the development process (see section 4) reports of usability tests and an acceptance test will be conducted. In addition to the report of the acceptance test, which includes information about advantages and disadvantages of 2S applications over traditional (unsynchronized) knowledge sources like Wikipedia or Google, a technical comparison of visualization prototypes and traditional (unsynchronized) knowledge sources will be conducted and summarized.

A concept for preparation process for data visualization in context of 2S scenarios will be created and tested. As result of a test with expert of that field (e.g. broadcaster and producer) there will be a report.

Finally a tested framework, which includes all relevant parts of a Second Screen application (e.g. content creation, synchronization, different types of visualization), and guidelines for designing and developing mobile data visualization for Second Screen applications, which are synchronized with the broadcast, will complete the thesis.

6 STAGE OF THE RESEARCH

Before I started my doctoral studies in computer science in January 2014, I had the chance to do research in a project where we developed an online concept for a science magazine including a concept for a 2S application without focussing on data visualization as a first step.

In summer 2014 a next step was to develop a functional prototype for a second screen framework with basic audio synchronization. Figure 2 shows an overview of the 2S framework. We developed a backend where TV producers and editors can define the 2S content and a 2S application that runs on iOS devices. The synchronisation between smartphone and TV works with audio fingerprinting.

Currently I work on a detailed state-of-the-art analysis for mobile interactive data visualization. Literature will be researched and evaluated based on structured criteria.

At the moment I also prepare a proposal for getting a research grant for this project together with colleagues.

6.1 Next Steps

A next step will be to determine data visualization types for mobile touch usage. Therefor I have to get an overview of relevant visualization types and evaluate them for mobile touch usage. The selection is based on the chosen 2S scenarios. In addition a survey on touch gestures in context of the determined visualization types is necessary. It is important to know which gestures can be used with different visualization types on mobile touch devices. To complete the basic survey on data visualization for mobile devices visualization libraries and frameworks have to be evaluated whether they can be used for developing data visualization for mobile touch devices.

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