

netidee Call11 (2016) ID 1587

# Information Visualization in Multi Device Ecologies

ENDBERICHT

KERSTIN BLUMENSTEIN VERSION 2

# Activity, Progress and Results

## WP1: State of the Art Analysis

During this work package, the goal was to research the state of the art of relevant fields including interactive exhibits in museums, data visualization in multi-device ecologies (MDE), data visualization on mobile devices as well as situated action models.

#### **Interactive Exhibits**

For the state of the art on interactive exhibits we evaluated 39 installations/museums. Methodically, we used literature research for 25 exhibits as well as an observation of 14 museums.



Figure 1: Extract of the matrix of interactive exhibits. Installations are arranged in columns grouped by color according to the developer of the installation. The main categories are grouped by color (Target group = blue, Devices = orange, MEETeUX tags = green) in rows. The installation columns colored with a darker grey background and marked with a star show the installations/museums visited by the team of MEETeUX.

In addition to the draft of the chapter in my thesis, the result of this research is a research document in German<sup>1</sup> as well as a matrix which overviews the categorization of the researched exhibits (see Figure 1)<sup>2</sup>.

Results show multi-device usage is present in interactive exhibits. "Bring your own device" is already a focus. However, the visitors' own device is not directly connected to any other used device.

### Data Visualization in Multi-device Ecologies

The chapter about data visualization in multi-device ecologies is based on a systematic review of the scientific literature of major information visualization and human-computer interaction venues (e.g., IEEE InfoVIS, IEEE IV, ACM ISS, ACM CHI). In total, we had a look through 16.593 papers. 21 have relevance for this state of the art. These paper focus on visualization of abstract data in co-located settings. Interestingly, more than a half of these papers (16 of 21) were published at ACM ISS (Interactive Surfaces and Spaces).

To get an extensive overview we categorized the papers with the following main categories (see Figure 2):

- Device type
- Multi-screen design pattern
- Type of data
- Type of visualization

Some interesting facts gathered from this survey: There is only few research in the area of visualization in multi-device ecologies. From the technical side, multi-touch tables are often combined with other devices. However, this is true for papers published before 2014. During the last years, smartphones were not the main target device in multi-device ecologies. Since 2014, stitching (the visualization is split up on various small devices) as multi-screen design pattern gets more interesting for researchers. Often, such systems are used for the purpose of collaboration in scientific literature. Only one paper (Maquil, Moll, & Martins, 2017) presents a museum's exhibit.

Currently, this chapter is in refinement for a submission as article for the journal TVCG (IEEE Transactions on Visualization and Computer Graphics).

<sup>&</sup>lt;sup>1</sup> <u>http://meeteux.fhstp.ac.at/wp-content/uploads/2017/06/Recherche MuseumsInstallationen 20170426.pdf</u>

<sup>&</sup>lt;sup>2</sup> <u>http://meeteux.fhstp.ac.at/assets/matrix/</u>



Figure 2: Extract of the matrix of scientific papers focusing on data visualization in multi-device ecologies. Papers are arranged in columns. The main categories are grouped by color (Devices = blue, Data type = orange, Visualization type = green, Multi-screen-design pattern type = red) in rows.

### Data Visualization on Mobile Devices

Based on the research I had published in 2016<sup>3</sup>, worked on a state of the art about data visualization on mobile devices. The paper concentrates on evaluation of visualizations on mobile device. Thus, the chapter had to be rewritten completely to give an exhaustive overview about such visualizations without the evaluation focus. In addition, the researched papers were updated with newer publications.

We gathered 15,061 publications from seven conferences (e.g., ACM Mobile HCI, ACM CHI, IEEE InfoVis, IEEE IV) over 14 years and ended up with 55 publications which deal with 2D information visualization on mobile devices. All papers were further investigated and systematically characterized along the following main categories (see Figure 3):

- Device type
- Type of data
- Type of visualization
- Context of usage

<sup>&</sup>lt;sup>3</sup> http://dl.acm.org/citation.cfm?doid=2993901.2993906



Figure 3: Extract of the matrix of scientific papers focusing on data visualization on mobile devices. Papers are arranged in columns. The main categories are grouped by color (Devices = blue, Data type = orange, Visualization type = green, Context of usage = red) in rows.

Some interesting facts gathered from this survey: Smartphones were not the main target device – tablets are more important. Between 2007 and 2012, there was plenty of research on map visualizations. Nowadays, there is no focus recognizable on a specific type of visualization. As we know usage environments of mobile devices vary significantly. So, context of usage is very important for designing and evaluating applications for mobile devices. However, only half of the papers define a context of usage.

### Situated Action Models

I started the research about situated action models. Due to health problems, it is not finished until now. What I have done so far, I have researched and categorized several models. Those models fit in three main categories:

- Cognitive models
  - Model Human Processor, GOMS, Cognitive Complexity Theory (CCT), Collaborative Action-based Production Systems (CAPS), Soar
- Contemporary cognitive architect
  - o LICAI/CoLiDeS, CoLiDeS Executive Process-Interactive Control (EPIC), ACT-R 5.0
- Post-cognitive theories
  - Distributed cognition, activity theory

I still have to write this chapter.

## WP2: Service design

This work package was finalized in conjunction with the project MEETeUX. Within this project, we created a service design document based on the research about interactive exhibits. In this document, we defined personas and requirements for our multi-device ecology as well as the basic functions and use cases, which goes beyond information visualization in multi-device ecologies. However, it builds the basis of the implementations for my thesis.

## WP3: Development of concepts

Like WP2, I am working on WP3 in conjunction with the project MEETeUX. This work package is still ongoing.

What we have done so far: As a first step, we developed the technical concept for the multi-device ecology. Afterwards, we built up the basic technical setting addressing smartphones (iOS and Android), multi-touch tables and large vertical surfaces. The software code of the project is published in several repositories on GitHub (entry point: <a href="https://github.com/fhstp">https://github.com/fhstp</a>, license: BSD-3-Clause).

In addition, we conducted several workshops (with internal team members and external exhibits experts) to define implementation ideas. Finally, we created an idea document which describes the process and the ideas in detail. Still ongoing is the creation of the visualization and interaction design concepts for these ideas.

### **Publications**

During the last year, I could publish four papers which are related to my thesis topic. All papers are in the area of visualization in multi-device ecologies.

ACM on Interactive Surfaces and Spaces (ISS)

Accepted paper submission at ACM ISS 2017 in Brighton, UK.

Blumenstein, K., M. Kaltenbrunner, M. Seidl, L. Breban, N. Thür, and W. Aigner, "Bringing Your Own Device into Multi-device Ecologies - A Technical Concept", Proceedings of the 2017 ACM on Interactive Surfaces and Spaces: ACM, 2017.

In addition, I submitted my thesis at ISS Doctoral Symposium. The DS chairs did not receive enough submission. Though, the symposium did not take place.

International Conference on Human-Computer Interaction with Mobile Devices and Services (Mobile HCI)

Accepted paper submission at ACM Mobile HCI 2017 in Vienna, Austria.

Blumenstein, K., C. Niederer, M. Wagner, W. Pfersmann, M. Seidl, and W. Aigner, "Visualizing Spatial and Time-Oriented Data in a Second Screen Application", Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services: ACM, 2017.

#### Forum Media Technology

Accepted paper submission at 10<sup>th</sup> Forum Media Technology 2017 in St. Pölten, Austria.

Blumenstein, K., B. Margarethe Eggert, M. Grandl, E. Kasser-Höpfner, K. Kratzer, J. A. Löcker-Herschkowitz, G. Neubauer, and F. Wiencek, "KuKoNö – KulturKontext Niederösterreich", Proceedings of the 10th Forum Media Technology and 3rd All Around Audio Symposium: CEUR-WS, pp. 78-82, 2017.

#### **IEEE Vis**

Accepted workshop paper at IEEE Vis 2017 – Vis in Practice – Visualization Solutions in the Wild in Phoenix, USA.

Blumenstein, K., B. Leitner, N. Thür, A. Kirchknopf, M. Seidl, and W. Aigner, "LiveVis: Visualizing Results of Second Screen Surveys in Real Time at TV Stages", Workshop Vis in Practice - Visualization Solutions in the Wild, IEEE VIS 2017, Phoenix, Arizona USA, IEEE, 2017.

# **Future Commitments**

The finished thesis will be published at the netidee website under CC-BY-SA.

Additionally, I would like to commit for blog posts in the future about the progress until my thesis is finished. This stipend will be mentioned in every future publication which is related to my thesis.

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