Public Displays
Understanding the Future of Digital Signage

Vorlesung „Advanced Topics in HCI”
Prof. Dr. Florian Alt, SS 2015
Motivation
Tabs  Pads  Boards

[Weiser, 1999] Ubiquitous Computing
The Lightning Man
Persepolis
Littfass-Säule

The Motogram

Source: IEEE Pervasive Computing
Digital City Light Posters

Source: Wall AG
State-of-the-Art Displays

Interactive Displays
Last Week in CHI 2015
BaseLase

An Interactive Focus+Context Laser Floor

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Introduction
Characteristics of Digital Signage I

• Push-based distribution
  – Advertisements
  – Information dissemination
  – Emergency announcements

• Context-specific content
  – Content related to physical context
  – In contrast to many other communication media (Exception: World Wide Web)
Characteristics of Digital Signage II

• Multimedia content
  • Moving images
  • Interactive applications
  • Games

• Easy to update and efficient use of physical space
  • Remote updates
  • Frequent change of content
  • Efficient use of physical space

Source: Davies et al., 2014
Advantages over Physical Signage

• Facilitating frequent, timely updates
• Increasing accuracy and provision of highly dynamic information
• Improving the aesthetics of a space (digital artwork, video, other media)
• Personalized interactive content
  • Promote viewer engagement
  • Encourage social interaction with the space
Shortcomings of Digital Displays

- Hard to understand how many people see digital signs
  - Difficulty to establish new business models
- No equivalent to click-through rate
  - Makes encouraging and tracking user actions difficult
- Encouraging passersby to see and interact with content
  - Creation and distribution of engaging content is key
  - Public engagement with public display is in general low
  - Viewers have become skilled at ignoring them (display blindness) [Müller et al., 2009]
  - Users look at displays in general for <2 seconds
Opportunities

“For advertising-based public display networks to become truly pervasive, they must provide a tangible social benefit and be engaging without being obtrusive, blending advertisements with informative content.” [Alt et al., 2012b]
• Falling cost of hardware means that an increasing number of displays are being deployed.

• Currently these display networks are typically closed – as a viewer you have no way to get your content or applications onto the display network.

• Can we utilize the full benefit of these displays – and go beyond adverts and MTV.
Involved Research Communities

- Graphics Communities (creating video walls, etc.)
- Ubiquitous Computing Community
- Computer Vision
- Social Sciences
- Commercial Sector

Digital Signage, Public Display, Pervasive Display:
Collections of digital displays deployed in public or semi-public space. [Davies et al., 2014]
Outline

Audience Behaviour

Interaction Techniques

How to evaluate public displays?
Audience Behavior
How people act in the vicinity of public displays
Spatial Models
Spatial Model of Interaction [Prante et al., 2003]

Hello.Wall

• Wall-sized ambient display employing Viewports to sense users in the vicinity
• Interaction with the display based on RFID
Spatial Model of Interaction  [Prante et al., 2003]

Hello.Wall

1. Ambient Zone
2. Notification Zone
3. Cell Interaction Zone
Refined Spatial Model of Interaction
[Vogel & Balakrishnan, 2004]

• Dividing cell interaction zone into subtle and personal interaction zone

• Generalizing idea of a notification zone into an implicit interaction zone

• Neutral state: ambient display as anchor point for subsequent interactions

• Relation to Hall’s theory of proxemics
Refined Spatial Model of Interaction
[Vogel & Balakrishnan, 2004]
Discussion

- Spatial models geared towards information presentation
- Mainly suitable to model single-user interaction
- No mechanisms for modeling how users move back-and-forth between different zones
Temporal Models
The Public Interaction Flow Model
[Brignull and Rogers, 2003]

- Three activity spaces
  - **Peripheral awareness activity**: situations in which users are primarily socializing; aware of the presence of the display but not focussed yet
  - **Focal awareness activities**: user attention shifts towards display (talking about content, watching the screen)
  - **Direct interaction activities** (explicit interaction with the content)
- Thresholds lead to people switching between activity spaces
- Strengths: supports multi-user interaction; takes people moving between activities into consideration
- Weakness: disregards implicit and explicit interaction from a distance
The Public Interaction Flow Model

[Brignull and Rogers, 2003]
The Audience Funnel
[Müller et al., 2010]

- Focuses on observable audience behavior
- Consists of several interaction phases
- Attempts to model the probability of users transitioning between phases (conversion rates)
1. Passing-By
2. Viewing and Reacting
3. Subtle Interaction
4. Direct Interaction
5. Multiple Interaction
6. Follow-up Actions

The Audience Funnel
The Audience Funnel

• **Strength:**
  Can be used to describe conversion rates and hence provide a measure for success

• **Weakness:**
  No social interaction between viewers; rather linear process

• **Modeling is just the first step:**
  – How to engage users with display?
  – How to move potential viewers throughout the various phases of engagement?
Quantifying Attention

Requirements

- Presence
- Position and Orientation
- Trajectory (Velocity & Direction)
- Body Posture
- Head Orientation
- Gaze Direction
How to Determine Gaze Direction

• Obtaining head orientation
• Extracting facial features (eye corners)
• Detecting pupils
• Calculating gaze vector

Based on:

Reading Recommendation:
Data Recording

- RGB Video
- Depth Video
- Gaze Direction
- Skeleton Data
- User Position
- Trajectory
Interaction in Public Space [Müller et al., 2010]

- **The presentation of self**
  - People want to maintain their role
  - Displays are a stage, design for introvert and extrovert people
- **Control of access to self**
  - People do not like to be unduly approached
- **Data privacy**
  - People do not like to be spied upon
- **Public Nature of Space**
  - You can not control the environment of the display
- **Social behavior**
  - People do not like to stand in the way of others
Calm vs. Engagement

- **Calm Displays** [Weiser and Seely, 1997]
  - Should slide effortlessly between center and periphery of attention
  - Should blend into the environment
  - Should be easy to ignore

- **Engaging Displays** [Rogers, 2006]
  - Should be fun to interact with
  - Should engage, inspire and entertain the audience
  - Should attract attention

Displays may not be used at all if they fail to attract attention!
Tools vs. Toys [Müller et al., 2010]

Tools

• Traditionally, public displays are viewed as tools.
• For tools, motivation for use is some external goal
• The most important criteria for tools are usefulness and utility.
• What to optimize:
  – Time (Less is better)
  – Errors

Toys

• The most important criteria for toys are motivation.
• What to optimize:
  • Conversion rates
  • Fun
  • Interaction times (More is better)

It seems more appropriate to see public displays as toys rather than tools!
Engaging Users
How to make people interact in public space
• HCI often assumes that the user is aware of the computer in the first place

**This is not the case for public displays!**

• Displays are installed in public space where they compete for audience attention
Attracting Attention
Understanding Attention

[Müller et al., 2010]

- Attracting attention is difficult (first click problem)
- Most displays receive little attention
- Naive approach: use stimuli to attract attention
  - Challenging in public space
  - Does not guarantee the user looks because many objects are competing for attention
- Another approach: use physical objects
  - Animatronic hands: physical attract loop shown to be twice as effective as a virtual attract loop
  - Drawback: less flexible, difficult to update with new content
Managing Attention

• **Behavioral Urgency** [Franconeri and Simons, 2003]
  - Attention is captured by stimuli that indicate the potential need for immediate action (e.g., an animal approaching)
  - Examples: abrupt appearance of new objects, luminance contrast changes, moving and looming stimuli

• **Bayesian Surprise** [Itti et al., 1998]
  - Bottom-up visual attention: measures the difference between posterior and prior beliefs about the world
  - Model predicts attention based on high entropy, contrast, novelty of motion
Managing Attention

• **Honeypot Effect** [Brignull and Rogers, 2003]
  - A crowd gathering around a display seems to attract further attention, drawing more people to the display

• **Change Blindness**
  - Effect that describes how to reduce the attention-attracting effect of changes in display content (important when content should be changed without the viewer noticing)
  - Examples: blanking an image, changing perspectives, displaying mud splashes, changing information slowly, changing information during eye blinks or saccades, changing information while occluded
• Today, people do not expect public displays to be interactive
• Enforced through many displays being used primarily for advertising
• Issue likely to become more apparent as LCD is replaced with technologies that more closely resemble traditional paper
• Passersby might not even notice that a surface is digital
Communicating Interactivity  [Müller et al., 2012]
Interactivity Cues

- Call-to-action
- Attract sequence
- Analog signage
- Honeypot effect
- Persons inviting passersby

→ User Representation
Interactivity Cues

Image-based Matching

Correlation-based Matching

Source: [Müller et al., 2010]
Lab Study: Comparing Interactivity Cues
Significant effect for representation on
- selection time (ANOVA): $F_{3,45} = 80.76, p<.0001$
- accuracy (ANOVA): $F_{3,45} = 43.09, p<.0001$

Time to Understand Interactivity
Field Study

- Measurement for 11 days
- 1500h video
- Semi-manual coding
  (cohen's kappa = .75)
- Observations and interviews
Conditions

Call-to-Action

Inadvertent Interaction
Findings: Number of Interactions

<table>
<thead>
<tr>
<th></th>
<th>no representation</th>
<th>silhouette</th>
<th>mirror</th>
</tr>
</thead>
<tbody>
<tr>
<td>call-to-action</td>
<td>67</td>
<td>59</td>
<td>79</td>
</tr>
<tr>
<td>inadvertent</td>
<td>60</td>
<td>87</td>
<td>150</td>
</tr>
</tbody>
</table>

Significant effect for

- interactivity cue (call-to-action vs. inadvertent interaction) (ANOVA): $F_{1,11} = 12.6$, $p<.001$
- user representation (ANOVA): $F_{2,22} = 13.1$, $p<.005$
- user representation * interactivity cue (ANOVA): $F_{2,22} = 6.8$, $p<.005$
The Landing Effect
The Honeypot Effect
Looking Glass - Summary

- Image representation is a powerful cue to communicate interactivity.
- Developers of public display applications should design for the landing effect.
- Attract many people to interact (honeypot effect).
- Almost all people interact in groups.
Immediate Usability

• After people notice interactivity, **immediate usability** is important

• Recommendations [Kules et al., 2004]
  • Implement an attract sequence; clearly indicate how to end the attract sequence and begin using the system (e.g., call-to-action)
  • Support zero-trial learning: users should be able to use the interface after observing others or using it themselves for a brief period of time (15-60s)
  • Encourage users to immediately interact with the content
  • Users not immediately being successful often simply abandon the device (already delay of a few seconds is problematic)
  • Users think device is not interactive or broken
Motivating Further Engagement

• How to motivate people to interact?
  • People do not go out to look at a public display but tend to come across a public display (e.g., bus stop)
  • They become motivated by external factors to look
• Greater Trend:
  Spread of computer usage from the workplace into public life
  • Display to serve a range of functions (helping users achieve tasks to more speculative forms)
• Task-oriented theories:
  Regard the “how” of an interactivity, but not the “why”

Significant need to advance understanding of the motivation behind users’ activities!
Potential Motivating Factors  [Michelis, 2009]

- **Challenge and Control**
  - Can help to motivate users but must be carefully balanced
  - Too little challenge leads to boredom, too much challenge leads to anxiety
  - People strive for an optimal level of competency

- **Curiosity and Exploration**
  - Curiosity as a key characteristic of intrinsically motivating environments
  - Interaction should be neither too complex nor too trivial
  - Interactive elements should be novel and surprising but not incomprehensible
  - User should have initial expectations for how the interaction proceeds but these should only be partially met
Potential Motivating Factors [Michelis, 2009]

- **Choice**
  - Motivation for particular behavior increases if people can select between alternatives

- **Fantasy and Metaphor**
  - Imaginary settings appear to have a motivating effect, particularly if constraints of reality are switched off so that one imagines possessing new abilities
  - Extent to which interactive environments inspire fantasy determines their attractiveness and generates interest

- **Collaboration**
  - Interaction with other human beings
  - Ability to influence the interaction of another person is motivating
Enticing Interaction

Attracting Attention

Communicating Interactivity

Enticing Interaction

Motivation ↔ Understanding Interaction

Provide

Audience
Interaction Techniques
Enabling Users to Interact with Public Displays
Overview [Davies et al., 2014]

• By providing support for user interaction a wide range of new features can be enabled
  • **Navigation**
    • Browse content on the display
  • **Expression of interest**
    • Tailoring the content displays show
  • **Content takeaway**
    • Retrieving content from displays using a mobile phone, email or URL
  • **Content upload**
    • Supporting user-generated content
Issues in Supporting Touch

• Users need to be able to physically reach the screen
• Screen protection: prevent theft, prevent access to controls, be resistant to everyday knocks
• Screen visibility
• Screen maintenance
Audience Expectations

• Currently no commonly agreed way of communicating interactivity
• High user expectations with regard to touch due to smartphones
  • Multi-touch
  • Touch gestures (pinches and flicks)
• Support of multi-user interaction (closer to tabletop /surface computing than to phones)
Touch Technologies

• **Resistive touch**
  • Two layers of resistive material, separated by an air gap
  • Advantages: very cheap to manufacture
  • Disadvantage: not as responsive as capacitive sensing

• **Capacitive sensing**
  • Determines touch location based on change in capacitance
  • Disadvantage: relatively inaccurate, need to be touched by something conductive (gloves in winter!)
  • Advantage: does not require pressure, better user experience

• **IR touch screens / Optical touch screens**
  • Use sensors around the edge of the screen
Mid-Air Gestures
Motivation for Mid-Air Gestures

- Suitable for displays at a distance that cannot be easily reached.
- Many users are reluctant to use touch screens for hygienic reasons, particularly in public spaces.
- Often a catalyst for performative interaction.
- Selection and text entry difficult.
Meaningful Gestures

- No commonly accepted gesture set for interacting with public displays
- Researchers and developers often need to create their own gesture set

Requirements

- Gesture set should **draw upon existing operations** that users are familiar with (pan and pinch gesture from smartphones)
- Gestures should be **coherent**, making it easier for the viewer to understand which gestures are supported by a system
- Gestures need to be **easy to recognize and easy to teach** (next slide)
Recognizing Gestures [Walter et al., 2013]

- Delimitation of beginning of gesture (registration), continuation, and end of gesture (termination)

- **Difficult to recognize for mid-air gestures compared to touch**

- Possible solutions
  - Multimodality
    - Combining touch and speech: “put that … there”
    - Needs to be discovered
    - May be inappropriate in certain environments (speech in a museum)
  - Reserved actions
    - Drawing a certain form in the air (e.g., a question mark)
  - Clutching
    - Users explicitly signal the system that it needs to engage the gesture recognizer
Teaching Gestures [Walter et al., 2013]

• Major challenge: informing viewers of the display of the gestures that can be used to interact with the system
• Many gestures are not intuitive! Need to help the user discover possible gestures
• Present cues using
  • Spatial division (splitting the screen into one area with content and one where the gesture is explained)
  • Temporal division (the regular content is temporally interrupted with the gesture cue)
  • Cue integrated with content
• Spatial multiplexing found to be best as it does not interrupt the content (interruptions may increase the tendency for users to leave the screen)
Teaching Gestures [Walter et al., 2013]

• Learning from mouse and touch interfaces
  • Showing videos (GestureBar)
  • Displaying hand poses for registering a gesture (ShadowGuides)
• Difficult to apply to public displays
  • Prior knowledge about modality required
  • Approaches designed for goal-driven applications (as opposed to playful display applications); users aware of available commands
  • People neither aware of interactive capabilities nor how they can interact or whether gesture-based interaction is supported
Gesture Technologies

• Device-based techniques
  • Rely upon sensor worn on the body e.g., accelerometer or positioning sensors
  • Examples: Nintendo Wii, BeeCon BlueWand, Vicon tracking system and markers

• Camera-based techniques
  • Often favored in public spaces as user does not rely upon additional gear
  • One or more cameras required to capture scene; image analysis techniques to extract information on body posture or position of the user
  • Examples: Microsoft Kinect (information on body, hands and fingers are detected and matched against skeleton model), camera and point light source to track user’s hands
Mobile Device Interaction

Bike for sale
Good bike for sale! Basis for negotiation: 90 €

Mattoja
- muutama sileäksi kudottu matto - ison olohuoneen matto - pienempi käytävämatto - väri valkoinen

Pesuhuoneen kattoon asti ylettyvä hyllystö
- muovia - väri valkoinen - hinta 5 euro
Using Smartphones for Interaction

• Gateway to devices in the local physical environment
• Personalized content to reflect the interests of viewers
• Express preferences and communicate with nearby displays
• Longitudinal personalization
Examples

- **InstantPlaces and eCampus (Bluetooth)**
  [Jose et al., 2008], [Storz et al., 2006]
  - Altering device names to tag features of their identity and link to their flickr profile

- **Tacita (WiFi fingerprints, GPS, Bluetooth)**
  [Davies et al., 2014b]
  - Uses smartphone to collect user preferences that are communicated to cloud-based applications for presentation on nearby displays
  - Reverses the traditional pattern of announcements, requiring a user’s mobile device to determine its proximity to a display
  - Personalization requests themselves are issues via a trusted application
Interaction

• Beyond form of identification, smartphones can be used to add interactivity to displays (e.g., as remote controls)
• Using traditional communication functionality of the device (e.g., SMS), input mechanisms (e.g., keyboard, touchscreen), or additional technologies (NFC)
• Novel forms of interaction:
  • Touch projector enables interaction with remote displays using a live video image on the device [Boring et al., 2009]
  • Using the flashlight of a phone and a display camera to create a novel pointing device
  • Using phones for gaze input?

Source: [Boring et al., 2010]
Co-Displays and Cyber-Foraging

• Smartphone user struggling with limited screen real estate of the device can forage a nearby display and transfer content for clearer personal viewing or sharing

• Individual view: Smartphone as private co-displays to augment the view provided by public displays

• Making aspects of the public display content deliberately private
  • Content can be blurred out on the public display and be made visible on the phone

• Further output techniques: rotating compass combines a public display and feedback via vibrations on the mobile phone to support pedestrian navigation
Information Takeaway

• Takeaway functionality allows viewers to collect information from the display
  • Equivalent of tear off strips found on analogue signs or click-throughs on conventional web adverts
  • Technologies: QR codes and RFID

• Examples
  • Shoot&Copy: trigger fetching content over Bluetooth or GPRS
  • Digifieds: taking away classified ads using an Android app [Alt et al., 2010]
  • She: accelerometers to detect gestures in order to indicate selection of items on a nearby public display
Analysis

• Trend towards more interaction but no agreement on what form this interaction should take
• No standard for the types of interaction and gestures that are possible
• To avoid user confusion and to drive uptake of interactive displays it is important to begin to converge on standard tools and techniques for user interaction