MASTER IN COMPUTER SCIENCE

Safeguarding securely user privacy with ambient displays a study and use case

Dehon, Jean-Yves

Award date:
2018

Awarding institution:
University of Namur

Université de Namur
Faculty of Computer Science
Academic Year 2017–2018

Safeguarding securely user privacy with ambient displays : a study and use case

Jean-Yves Dehon

Internship mentor: Bruno Dumas

Supervisor: _____ (Signed for Release Approval - Study Rules art. 40)
Bruno Dumas

Co-supervisor: Antoine Clarinval

A thesis submitted in the partial fulfillment of the requirements
for the degree of Master of Computer Science at the Université of Namur

Acknowledgment

I would like to thank :

Bruno Dumas for his prompt support on regular basis and the time he spent helping me to define and work on this document

Antoine Clarinval (doctoral candidate) for his presence, advices and inputs during our regular meetings

My wife for her patience, supporting me during the master and reading this document

My children for letting me reduce the time spent with them during three years

All readers of this document

All teachers I had during the master for their knowledge and making mine bigger

Abstract

Today, everybody do has access to information. Public ones (train and bus schedules, University courses schedules, Open Data, ...) and private ones (e-mail, personal calendar, ...). The smart-cities are growing more and more and use some displays with public information like advertising, city maps, metro maps, ...

This document proposes an analysis to classify available ambient displays and identifies characteristics and guidelines to develop a new implementation.

When it comes to interaction with public data some design principles need to be followed. Going further the displays can offer interaction with private data. This is why the user's authentication is important. The user wants to be sure that his current session is secure and that the privacy of his data is respected.

The use case proposes an implementation of an electronic information board following the UX methodology and taking care of the recommendations from the courses received during the Master in Computer Sciences.

As all analyzed system doesn't offer all properties in terms of security, privacy, attractiveness, usability and public access, a study was done to propose a solution to display private data on a public display, while safeguarding securely user privacy.

Keywords

Ambient Display, Display Interaction, Display authentication, Display Private data, Display Public Data, Proxemic Interaction

Contents

Chapter 1

Introduction

Today data are available everywhere going from location data, advertising, schedules, e-mails, social network, and so on. The modernization of cities offers more and more ways to have access to those data using wifi access points to their citizens, better gsm data coverage, ... They can also give all those information by using another media : the ambient display. They can be almost anywhere and display public information easily : no need to have a person who will change the picture of an advertising. This can be done remotely. The bus or train schedules don't need to display all days, the display can show only the current schedule, inform the citizen about any delay or cancel.

Ambient displays aren't new, the ambientROOM is the right example : it shows that people need to be connected and receive information from the external world.

The state of the art reveals characteristics and classification of ambient displays. Existing public displays will be analyzed through those characteristics and classification. Those displays shows public data and some harmless located private data.

Display information is interesting but local data can be manipulated by the users and offers interaction. Designs principles are proposed as guidelines. Some systems will be analyzed using those designs principles.

Other studies shows that people using the display served as an attraction for more users. People most often notice the display when someone is using it. This is called the 'honey pot effect'.

The classification of ambient display covers also the interaction and proposed systems will be classified.

Design challenges appear with the interaction going from showing that the user can interact with the display to convince that the interaction doesn't need many

time or effort from him.

With interaction it is possible to display also private data. But the system can't show private data any time. It must have a specific distance between the user and the display before displaying private data. Those are the interaction phases. Transitioning from one phase to another offers to the user another level of privacy and another level of data displayed.

Displaying personal data forces to verify if the user in front of the display is allowed to see them. This means that authentication is important and necessary. An evaluation of different authentication system will be done.

After analysis, any of those authentication system offers at the same time : security, privacy, attractiveness, usability and public access.

Before interacting with private data on an ambient display, the display must show public data. A use case prototype will be first developed to display data in the university of Namur following the design principles and characteristics. The methodology used to develop the prototype consists of cycles with 4 steps : Analysis, Design, Implementation and Evaluations.

An electronic information board will be developed. Public data are a map of the building, a list of current courses and a list of news. A visual link using colors shows the room where the course is done. The development will follow the recommendations (modifiability, generalization and re-usability) so it can be transposed to another implementation in cities.

The display must provide to the students a secure access to their private data. A study will be done to propose a solution for the authentication and for taking care of privacy during the display of the personal data. The same methodology will be used but no prototype will be developed. After some cycles, the study propose a solution to the student a secure access to their private data while keeping privacy.

Chapter 2

Definitions

2.1 Ambient

Relating to the immediate surroundings of something.

the liquid is stored at below ambient temperature

Origin : Late 16th century: from French ambient or Latin ambient- 'going round', from ambire. [*Oxford English Dictionnary* 2018, (19)]

2.2 Display

Verb : Put (something) in a prominent place in order that it may readily be seen.

the palace used to display a series of tapestries

a notice was displayed in the booking office

Noun : An electronic device for the visual presentation of data or images.

The color display now costs £400 [*Oxford English Dictionnary* 2018, (19)]

2.3 Interface

A point where two systems, subjects, organizations, etc. meet and interact.

the interface between accountancy and the law

Computing : A device or program enabling a user to communicate with a computer.

a graphical user interface [*Oxford English Dictionnary* 2018, (19)]

2.4 Ambient Display

"*An ambient display can represent many types of data, from stock prices, time, weather forecast, presence of colleagues or status of system*" [Pousman and Stasko 2006, (21)].

"*Ambient displays are aesthetically pleasing displays of information which sit on the periphery of a user's attention. They generally support monitoring of non-critical information*" [Mankoff et al. 2003, (16)].

Ambient displays do not usually involve direct interaction with their surface. They have been developed to investigate the ways in which displays can be situated in physical settings, representing rhythms and movements of people in a space and increasing reflection and awareness of other users of space [Skog, Ljungblad, and Holmquist 2003, (27)].

They aren't necessary using Information Technology to display that information :

- A mechanical watch displays time
- A blackboard can show information about colleague presence
- An information board at the university displays information for students

2.5 Ambient Interface

An ambient Interface is an ambient display on which people can interact to change the information displayed :

- Have more details on a specific information
- Have personalized data

Chapter 3

Display

3.1 Ambient Room

The concepts of ambient displays and ambient interface aren't recent : in 1998 The Tangible Media Group created the ambientROOM [Wisneski et al. 1998, (32)]. The human inside the room is aware about information from external environment but in a closed box without any window. The purpose is to surround the user with an augmented environment. The platform uses "ambient media" : ambient light, sound, physical motion (used to catch the user's attention).

The ambientROOM is an implementation of context awareness software and hardware (see Figure 3.1).

" *A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.* " [Dey 2000, (9)]

Some people argue that personal computing isolates people but they have a need to feel connected to other ones, especially with the people they care about. Many of their prototypes are centered on information about the loved ones. Connecting people is an attractive and powerful application like e-mails, paging, telephones (Today, it is still the truth with e-mails, chat and social networks).

An active wallpaper shows the presence of other people. Using illuminated patches projected on a wall of the room. When the activity is low, the spots aren't moving, but when the activity increases, the spots are moving providing a visual display of remote activity.

Displays such like this can give people an indication of the state of the world around them. The Graphical User Interface (GUI) and ambient merge purpose and function. The background ambient displays co-exist and add value to fore-

Figure 3.1: The Ambient Room Entrance

ground tasks. The background information can be showed in foreground and vice versa. The user control this according to his personal needs, awareness or physical controls.

The user communicates with the external world using bottles, employed as graspable "containers" for digital content. The content is the data which the user will work with. Controls are build to be self-explanatory. The gesture of opening and closing a bottle is a simple way of accessing the information.

The user can use all his five senses to receive information. The first key choice, in designing an interface, is selecting which sense to use to inform the user. Some styles of mappings are more effective than others : many people reported that the sampled, looped sounds of water in the ambientROOM became annoying after months of repetition.

The study recognized that displays must be so abstract that users cannot infer their meaning.

At times when all displays where running at once, the ambientROOM was so full of brisk activity that people have difficulty maintaining concentration on foreground tasks. People must have the control of the thresholds of all those tasks but that can be done automatically according to the foreground task. Example : reading a text, don't display anything above it. Today, on some computer operating system, you can activate the "do not disturb" functionality of the os to stay focus on your work.

With the ambientROOM, there is a learning effect : people know how and where to look for information. The learning time was also evaluated to make the

ambient media more efficient.

3.2 Public Displays

After displaying some ambient information for one user, there is a need to extend this to more people, some researchers worked on developing displays which show urban data in the cities.

To display urban data, we have to take into account the cultural, environmental, legal or societal reality surrounding a specific place. To change the way inhabitants become aware and act positively for a more qualitative neighborhood, the communication support and the representation of data need to be changed becoming discursive and use pictorial representations. Changing this means making the identity of the place more tangible and relevant. The display wants to provide data about and for his inhabitants [VandeMoere and Hill 2012, (29)].

" *'Open Data' is a philosophy who encourages the free and transparent distribution of data without restrictions of copyright, governmental oversight, or other mechanism of control.* " [VandeMoere and Hill 2012, (29)]

The way of presenting information, situated in a local environment, should easily overcome the motivational and accessibility issues that come with traditional media communication format like mass mailings, on-line websites or smartphones applications. The data must be transformed or mapped through an explicit metaphor to be understood and perceived. To be useful, data need to be presented in an easily accessible and an understandable ways.

It is more a social visualization that has the ability to engage people in relevant topics which allows citizen and scientists to collaboratively discuss and analysis the data they collect [VandeMoere and Hill 2012, (29)].

The public display can play an important role in citizen's life by combining historical data and real-time sensor to provide a better understanding of a place. Qualitative feedback is important. However, those visual representations of the city still tend to be presented through websites or smart-phone applications, which are conceptually and physically separated from the current environment from which the data originates, turning the urban experience into a virtual one.

Displaying complex information within everyday urban space is not a trivial task, as most citizens are accustomed to ignore such public messaging, regardless of how large, brightly, or interactively the imagery might be presented.

Muller [Muller et al. 2009, (18)] investigated and observed that the location of a

screen is important. If the display is located where people expect to see advertising, they don't look at the screen. Displays installed in different locations inside of a university, showing information for students, received all attentions. Students even find the information interesting even if they already know the content. For the other displays located near by shops, café, mall : anybody was looking the screens and this way nobody founds the information displayed interesting.

That behavior is also known from the Web. People surfing on Internet 'automatically' ignore a zone of the screen where they expect to find an advertising or an uninteresting content.

3.3 Characteristics of an urban visualization

Displays implementations use common characteristics, we will analyze some examples through them.

3.3.1 Situated

It means that the visualization is embedded in a real-world, physical environment.

"

- *Contextual : a display attached to a house facade reflects the behavior of the resident household, smoke coming out of chimney represents pollution, a light-emitting artifact attached to a traffic light depicts a waiting time, and so on*
- *Local : the data is sensed, measured, or acquired within the physical environment immediately surrounding the display, or has been modeled into values that reflect the particular circumstances of the people, buildings, or activities within the local environment*
- *Social : The local population can easily identify with the issues raised through the data, ensuring a level of usefulness and utility that goes beyond a specific time or a specific individual user (persona)*

"[VandeMoere and Hill 2012, (29)]

Examples

- In Copenhagen [Colville-Andersen 2009, (8)] a display shows the daily and yearly total number of bicyclists who passed (see Figure 3.2).

Figure 3.2: Broadcast number of bicyclists who passed

- In the center of Helsinki the CityWall [Morrison, Jacucci, and Peltonen 2008, (17)] displayed some events that took place the city (see Figure 3.3). The display has a multi-touch surface. It has been reported that passers-by seemed more interested in the novelty and the playfulness of the interface than the content itself.

Figure 3.3: CityWall displays some events in the city

- The Tidy Street Project [Bird and Rogers 2011, (4)] : A huge historical line graph, showing the citizen's usage of electricity, was made manually with a chalk on a common road (see Figure 3.4).

Figure 3.4: Graph of historical electricity usage written on the street

- Pollstream - Nuage Vert [VandeMoere and Hill 2012, (29)]: It is a city-scale visualization of a powerful (though low-energy) laser light which transform a cloud emanating from an electricity plant chimney into a meaningful projection surface (see Figure 3.5).

Figure 3.5: Display surface according to energy savings

3.3.2 Informative

The data are different from those on posters and electronic announcement billboards in several ways.

“

- *Feedback : Urban data are created by city inhabitants and are different from services, time schedules, or other urban phenomena that exist independent*

of urban inhabitants. An urban visualization thus forms a factual mirror, which must dynamically change according to the activities of inhabitants to be truly believable (and potentially persuasive). Equally, it may be that the form of the visualization itself needs to change over time, in order to retain the interest of its regular passers-by

- *Insightful : The visual representation should be sufficiently intuitive to be comprehensible*
- *Consistent : The displayed information does not negate the meaning of it*

" [VandeMoere and Hill 2012, (29)]

Examples

- In Copenhagen [Colville-Andersen 2009, (8)] the display counts the number of bicyclist coming by.
- The CityWall [Morrison, Jacucci, and Peltonen 2008, (17)] displays some events that took place the city.
- The Tidy Street Project [Bird and Rogers 2011, (4)] : A huge historical line graph which reveals the historical electricity usage of the inhabitants of a street, contrasted to the average values of other UK regions.
- Pollstream - Nuage Vert [VandeMoere and Hill 2012, (29)]: More the local inhabitants saved energy, the larger the surface area will be.

3.3.3 Functional

The following aspects assure the effective functioning of a urban visualization, which corresponds largely to the requirements of common urban displays, including advertisements, road signs, council announcement boards, graffiti, and so on.

"

- *Medium : The visualization is designed as to reach a sufficiently large audience, irrespective of their technical expertise, cultural background, or motivation*
- *Participative : The data are shared by a community of people, encouraging participative and collaborative action and the sharing of common norms and values*

- *Opportunistic : The visualization is perceivable in the periphery of human attention, allowing viewers a free choice to dedicate their focus or attention. Accordingly, the information is not of vital or crucial nature*

- *Trustworthy : The data are showed in a way that accurately reflects the current situation. For instance, the sources of the data that were used are clearly mentioned and are publicly accessible*

- *Persuasive : An urban visualization should be ideally designed considering, or with the active participation of, the current local citizens, in order to create a feeling of ownership and personal involvement. Similarly, interactivity should be considered more widely than the standard keyboards, multi-touch surfaces, or smart phone applications in order to guarantee a wide public acceptance, by those "users" who typically are not conscious of current technological advances.*

" [VandeMoere and Hill 2012, (29)]

Examples

- In Copenhagen [Colville-Andersen 2009, (8)] : the goal of this display is also to persuade onlookers to commute more with a bike. The goal is not to be the first but to be the 500,000th and receive a free bike from the local administration

- The CityWall [Morrison, Jacucci, and Peltonen 2008, (17)] displays some events that took place the city and encourage people to participate

- The Tidy Street Project [Bird and Rogers 2011, (4)] : The goal is to persuade the citizens to limit their energy consumption

- Pollstream - Nuage Vert [VandeMoere and Hill 2012, (29)]: The goal is to persuade the citizens to limit their energy consumption

The data sources used in those examples are relatively 'simple' in terms of their technical implementation, however still hard to come by.

By using more and more electronic communication devices, the citizens do have tendency to reduce sociability. Displaying complex urban data on screens is a good technique to shape the next generation of public feedback. The displays can be a platform on which applications can be build to motivate people by exchanging

on topics relating to urban challenges. Many implementations are limited by representing a single data attribute, that misses the opportunity to present more dimensional and rich relationships that form the very basis of the city as a complex system.

The displays should include feedbacks loops on quality and satisfaction versus the historical data. This way the city can verify their investments, the impact of their decisions, road security adaptations on real-time traffic and so on. The cities are valuable and relevant sources of data that require rigorous aggregation, analysis, and public dissemination.

3.4 Urban visualization of private data

An investigation in Sydney [VandeMoere, Tomitsch, et al. 2011, (30)] was made to display some personal data in a street. They displayed energy consumption on the facades of houses. They made groups based on the conditions that the 11 householders accepted to collaborate with the study :

- Group A: public and personal displays
- Group B: private display
- Group C: no feedback

The study took 10 weeks. They display and collect data according to the group the citizens are in (see Figure 3.6):

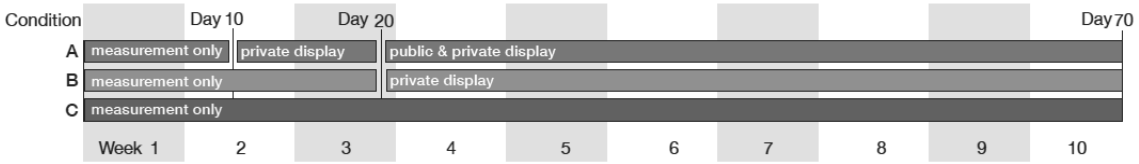

Figure 3.6: Collect data according to the group

During the study, the daily electricity usage statistics of several households were displayed on their respective houses, so that any positive or negative change in their habits became immediately comparable to those of other nearby households.

They were using chalkboards (see Figure 3.7) which were hanged on the facades of five different houses. The information was updated manually by the researchers, once a day.

Figure 3.7: Manual update with chalk

The boards included several visualization techniques in order to investigate the specific factors that influence the effective perception of the information by inhabitants and passers-by (see Figure 3.8).

Figure 3.8: Board displayed

- a : Marginal Notes for personalized messages or persuasive captions
- b : Daily Performances
- c : Neighborhood Ranking
- d : Historical Graph
- e : Pictorial Bar : it highlighted the occurrence of any sustained change, such as a succession of positive or negative changes in energy use by way of an explicit visual reward

3.4.1 Characteristics analysis

- Situated

  - Contextual : The board is attached directly on the house facade
  - Local : The data are coming from the house
  - Social : Graphs and ranking permit to identify actions

- Informative :
  - Feedback : The board is updated on a daily basis
  - Insightful : 'emoji' and graphs are easy to understand
  - Consistent : Data are refreshed daily and represent energy consumption

- Functional :
  - Medium : The data are visible from the street and reach all citizens
  - Participative : All data are for the citizens and they can collaboratively change them
  - Opportunistic : Data can be seen from the street and they 'just' display energy consumption
  - Trustworthy : Data are updated daily and people knows that they are coming from the official energy meter

The public display of the private energy data should have a positive and a sustained effect on their consumption triggered by the competition, social comparison or social pressure. But the effectiveness of comparing publicly the behavior of multiple persons with each other is still relatively contested : some past studies showed immediate and positive effects, others have revealed how people tend to be concerned about the apparent validity of the comparison groups. This comparison has some important drawbacks :

- Bad-performing participant change their behavior positively when they are compared to the others
- Good-performing people feel less encouraged and tend to the opposite as they are notified that they already have a positive behavior, and feel no immediate objection to move towards the "average"

While many real-time visualization techniques can be easily imagined, it becomes a challenge to design a publicly noticeable display that is cheap, sustainable in itself, easily updatability, acceptable by local residents. But also resistant to

the urban environment, including "real" aspects as materials, safety, vandalism, weather, council approval, privacy issues, and so on. This project also revealed some issues when urban data are put in the public realm :

- How people interpret "change" instead of absolute use values
- Their inept method of rewarding sustained behavior
- Inability to connect the insights derived from the visualizations into direct positive actions

More research is required on how to best present complex data in a public context, in terms of being understood as well as facilitating actionable sense-making.

3.5 Display Classification

Ardito [Ardito et al. 2015, (2)] reveals some classification of displays in terms of display setup, application purpose and locations. Many articles were analyzed and a classification was done using categories. The sum of the percentage may exceed 100% because a single paper can describe a system who do have more than one feature.

Here are the percentage of paper for each category :

Display Setup		Application Purpose		Location	
Category	%	Category	%	Category	%
Vertical	67	Productivity	54	City	17
Horizontal	31	Entertainment	39	Office	16
Diagonal	2	Social Interaction	25	Univeristy / School	9
Floor	3	Gaming	15	Conference	5
Other	8	Advertising	6	Third place	5
				Cultural site	4
				Shop	3
				Lab prototype	43

- Display Setup : This is the position of the display (see Figure 3.9)

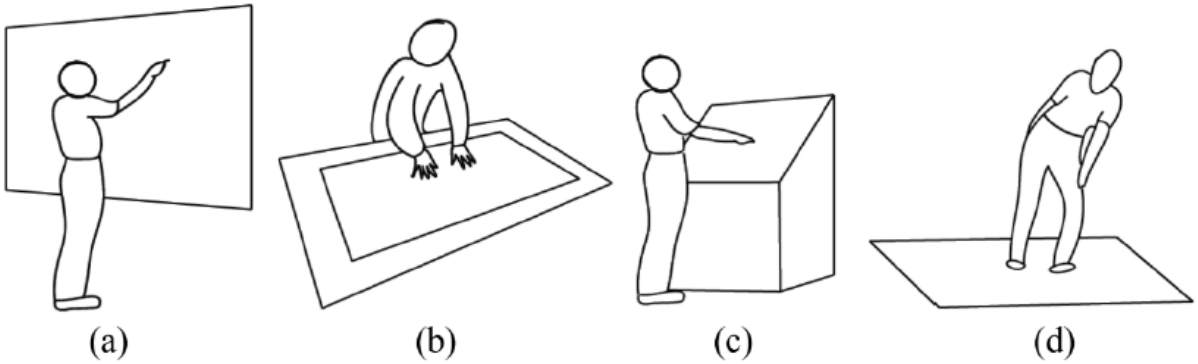

Figure 3.9: Display setups: (a) vertical, (b) horizontal, (c) diagonal, (d) floor

  - Vertical : Most installations are using vertical ones. This disposal is used in cities or university. It is convenient for passers-by who stay a short time in front of it. Many installations use multiple displays arranged in one layout
  - Horizontal : This is the best usage for interacting for a long period of time. People are sitting around the display while discussing and share the contents
  - Diagonal : This provides easier interaction for users situated in front of the lowest side. This permits more privacy than the horizontal installation
  - Floor : New installations use that layout most of the time for entertainment purposes
  - Other : Installations done in specific layout like a cylinder or a sphere. This allows to have different interactions on the same screen as the users don't see all the display at the same time.

  In the examples :

  Copenhagen bicyclist counter, CityWall and Residential Energy in Sydney are Vertical.

  Tidy Street Project is horizontal.

  The Nuage vert is Other.

  Those examples are in line with the percentage observed by Ardito.

- Application Purpose

  - Productivity : Application which have a specific utility for the users. Some do have a learning purpose like a display which ask questions about museums contents
  - Entertainment : Designed to entertain people going from surfing web to interactive bulletin in a café
  - Social interaction : Permit to retrieve some personal feedback or facilitate the discussion using social networking services
  - Gaming : Entertaining or learning games. Poker used with a tabletop multi touch display
  - Advertising : only 6% of advertising display are interactive
  - Temporal trend of application purpose : Designed to be specific to the users

  In the examples :

  Copenhagen bicyclist counter and CityWall are entertainment.

  Residential Energy in Sydney, Tidy Street Project and Nuage vert are productivity.

- Location : They are self-explained. Most of them are still in prototype stages.

  In the examples : all 4 are in cities.

Chapter 4

Interaction

With new technologies and presence of smart-phones and tablets, people foreseen interacting with ambient display and permit access to "on-demand" information.

There are many public places where displays are placed to support community and social activities. The major found issue that has been observed with this new form of interaction, is the resistance of the public to participate [Brignull and Rogers 2003, (5)]. The main reason is due to the feelings of social embarrassment that act as a barrier to the user experience when they interact in front of an audience [Brignull and Rogers 2002, (7)].

Agamanolis [Agamanolis 2003, (1)] found that half of the battle in design a public display is designing how the display will invite that interaction. Displaying people who already interact with the display invites other people to do the same.

As people become more experienced with interactive public displays, they are motivated to interact if it is clear what the system has to offer.

4.1 The honey pot effect

There is a social affordance around the display called the 'honey pot' effect. This means if people are showing interest about the display, it is giving out an implicit signal to other people that they are open to conversation and meeting other people [Brignull and Rogers 2002, (7)].

The Opinionizer is a public display that people could interact with while simultaneously observing others taking part. It is a shared display linked with a computer on which the user can type a few words and the interaction is cloned in real-time on the display. The system was installed during a party. At the beginning people going to the buffet (which wasn't far from the display) came forward

to try out the system. When helper tried to invite other people, some of them didn't want to because it might involve too much time or effort or that it would involve looking stupid in public. The key was to find a way of allowing people to observe its first use and get drawn to use it that way [Brignull and Rogers 2003, (5)].

Initially helpers added opinions themselves. After this, more people wanted to interact with the system. And when more people are using it, more other people wanted to follow suit.

This resulted in an increase of the rate of contribution on the system over time (see Figure 4.1).

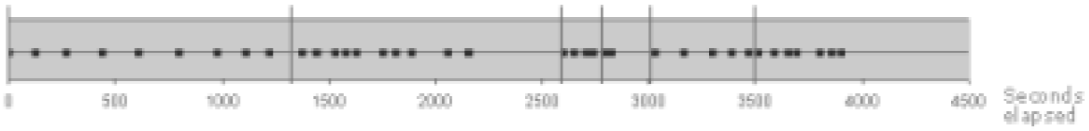

Figure 4.1: Opinionizer contribution rate over time

The Helsinki Institute of Information technology tried a large display in City-Centre which was installed during summer 2007, next to a café located between the main bus and train station, during 8 days, 1199 persons interacted with the system. The two stations are used by 400 000 passengers each day, and there is a great deal of pedestrian traffic past the display around the clock. They observed that only 18% of the users were individuals and in 19% of the cases, the display was already in use by someone else when a new user get closer to the display and started using it. As the display was used for 8.8% of his uptime this demonstrates that people using the display served as an attraction for more users. They noticed also that people most often notice the display when someone is using it [Peltonen et al. 2008, (20)].

" *The honey pot effect raises awareness of the public display to passers-by from viewing a group of people interacting with or watching around the exhibit* "[Xambó et al. 2017, (33)].

4.2 Design principles

In 2004 D.Vogel developed some design principles[Vogel and Balakrishnan 2004, (31)]. They are still up to date and still used in more recent research as the one made by Sahibzada [Sahibzada et al. 2017, (25)].

4.2.1 Calm Aesthetics

" *Ambient displays provide information in the user's periphery and are typically placed in a permanent location becoming part of their environment. Thus, one must carefully consider the aesthetics of the displayed information, and how the interface subtly reacts to input and fluidly signals state changes* "[Vogel and Balakrishnan 2004, (31)]

Examples

- The Opinionizer is a public display that people could interact with while simultaneously observing others taking part. The goal of the system was to create an interactive display that strangers felt comfortable and wanted to take part of the interaction [Brignull and Rogers 2003, (5)].

  The Opinionizer was placed in two party settings :

  - A book launch party held at a large international conference
  - A welcome party for new students just arrived at the university

  All people's post on the display were from the people who were in the room. Comments were displayed in a quadrant form with updates in real-time (see Figure 4.5).

- The Helsinki display in City-Centre shows in real-time pictures from Flickr who do have the keyword Helsinki (see Figure 4.2) [Peltonen et al. 2008, (20)]

- The interactive advertisement system is a display installed in the Weimar tourist information center. It displayed map, pictures of sites and walking information of the area (see Figure 4.3) [Sahibzada et al. 2017, (25)]

- The Dynamo system [Izadi et al. 2003, (13)] is a communal multiuser interactive surface. The Dynamo system has been designed as a large publicly accessible interactive surface that allows people to gather around, share, display and exchange media with others. The display shows always the last status. The users see the difference when they are coming back

- The two sided collaborative display [Li, Greenberg, and Sharlin 2017, (15)] shows data from the users in a "controlled" interactive environment. Tested with Pictures of cities around the world (see Figure 4.7)

Figure 4.2: Screenshot of CityWall with Flickr content

Figure 4.3: Map & pictures of sites

- The tangible music interface offers combination of objects to create and modify sounds. Sounds and music are known by almost all people. Drawings are displayed automatically when the tangible objects are disposed on the table (see Figure 4.4) [Xambó et al. 2017, (33)]

4.2.2 Comprehension

" *The information communicated by the ambient display must be comprehensible, even if rendered in an abstract manner. It may not be immediately understandable, but users should be able to discover meaning through subtle interaction* "[Vogel and Balakrishnan 2004, (31)]

Examples

- The Opinionizer is designed in a way that observing people initiate conversation with people standing beside them. People comment and after want to

Figure 4.4: Pictures of cities

interact. Having broken the ice that way, it could lead onto further topics of conversations.

The people who posted content could use avatar, speech bubbles or cartoons to add color or personality to their opinions.

A key issue in the system was to design the shared display that represents the content which anyone could observe or add to and which changed sufficiently overtime to continue to maintain the people's interest at the social event. The screen was also divided into four quadrants representing different backgrounds. The people could move the opinion to their preferred quadrant using a mouse. They could also move it outside of the quadrant (see Figure 4.5) [Brignull and Rogers 2003, (5)]

- The Helsinki display in City-Centre shows pictures from Flickr with regional keywords. People can directly recognize and identify them [Peltonen et al. 2008, (20)]

- The interactive advertisement system shows a map of the area and they can interact to find more information about the pictures of the sites [Sahibzada et al. 2017, (25)]

- The Dynamo system provides contents from people like media and pictures. The icons system permitted to identify the type of content people were shar-

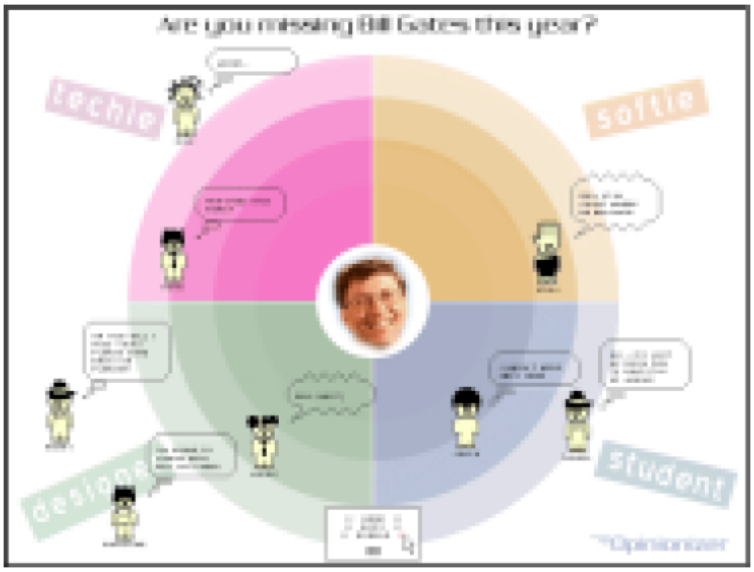

Figure 4.5: Opinionizer quadrant

ing and the type of interaction the display offers (see Figure 4.6)[Izadi et al. 2003, (13)]

Figure 4.6: Dynamo system interface

- The two sided collaborative display uses collaborative information in controlled environment so users are aware of the information displayed (see

Figure 4.7)[Li, Greenberg, and Sharlin 2017, (15)]

Figure 4.7: Pictures of cities

- The tangible music interface : users see the headphones and explicit icons [Xambó et al. 2017, (33)]

4.2.3 Notification

" *The display should notify and communicate with passers-by in a socially acceptable manner based on their level of attention and openness to receiving more information* "[Vogel and Balakrishnan 2004, (31)]

Examples

- People, talking in front of the Opinionizer, look at the display and react directly to any update made by another user [Brignull and Rogers 2003, (5)]
- The interactive advertisement system displays pictures of sites in the area [Sahibzada et al. 2017, (25)]
- The Dynamo system also allows media to be packaged up into media parcels that can be left for others. Media parcels can be thought of as containers that can encapsulate multiple media items. Parcels can be directed to one or more users of the system so when they came back they are aware of the new package availability[Izadi et al. 2003, (13)]

- The two sided collaborative display shows directly the other people screen so it is in real-time. The other user can leave an information opened when he's leaving [Li, Greenberg, and Sharlin 2017, (15)]

- The tangible music interface doesn't display information it is just a support for the interaction. But, during sleep mode, the table displays "Place the objects on the table" [Xambó et al. 2017, (33)]

4.2.4 Immediate Usability

" *Prior training should not be required to use the display. To encourage learning by exploration, responsive display techniques can lead users into subsequent phases of interaction. If some explicit interaction techniques are difficult to discover, the system should demonstrate these techniques at appropriate times* "[Vogel and Balakrishnan 2004, (31)]

Examples

- The Opinionizer uses a keyboard and a display which are understandable directly by the users. Overtime people are using the system without any explanation from the helpers, they appeared to have picked up this knowledge through observing over the shoulder of others interacting with the system.[Brignull and Rogers 2003, (5)].

- The Helsinki display in City-Centre : The main challenge was to support interaction for any user, from a child to a senior citizen, not requiring special skills or previous knowledge. Moving, scaling and rotation of pictures follows direct manipulation principles : a user can grab an image by putting a hand on it. The picture follows the hand movements when the user shifts his hand. Rotating and scaling are possible by grabbing the picture at more than two points (example : by two hands or two fingers of the same hand) and then either rotating the two points around each other or altering their distance.

  Many people were using the display with one hand only. It can be justified by the fact that most of the people in Helsinki were carrying a bag, skateboard, camera, mobile phones or items.

  Some people were also users that seemed to take the content of the pictures seriously, but a vast majority seemed to focus on playing with the interface.

This was visible in the intension of games and different kinds of nonsense activities at the display.

16% of the use situations at the display took place when the display was interacted by people who were strangers. It showed that it was easy to use the touchscreen just by following the example of the others, and nobody actually need to read the instructions printed next to the physical display [Peltonen et al. 2008, (20)].

- The interactive advertisement system [Sahibzada et al. 2017, (25)] : 3 phases were tested
  - No interaction
  - Body interaction : the body silhouette is shown on the device and the user moves to interact with the system
  - Mobile device interaction : the usage of a phone is needed to interact with the system

  It was very effective that the body interaction was better understood and easier to use.

- Dynamo promotes shoulder-to-shoulder collaboration by allowing multiple users to interact simultaneously on the same surface. Each user interacts with the surface through an interaction point. An interaction point comprises of input devices capable of delivering mouse, text and media input to the system. Two broad forms of interaction points are provided :
  - Base interaction points : mouse, keyboard, usb disks, digital camera
  - Mobile interaction points : laptop or smart devices delivering media from their internal disks

  [Izadi et al. 2003, (13)]

  The usage of the system is clear and known by the users

- The two sided collaborative display uses a touch screen with areas reproducing a phone or tablet movement [Li, Greenberg, and Sharlin 2017, (15)]

- The tangible music interface uses headphones and objects with icons and explanation that are easily understandable by people [Xambó et al. 2017, (33)]

4.2.5 Shared Use

" *To take advantage of a large display, multiple users should be able to share the system either individually or collaboratively whether interacting implicitly, explicitly, or simply viewing the ambient display* "[Vogel and Balakrishnan 2004, (31)]

Examples

- The goal of the Opinionizer was to encourage people to create and display content for public viewing, that would encourage conversation and socialization between people (Borovoy [Brignull and Rogers 1998, (6)] observed that in such social settings it is often the case that newcomers are 'outside the network' and find very difficult to break the ice and become part of it).

  About 40 persons typed their opinions. Over 60% of them where humorous. People were using their first names or nicknames as identifier. This was interesting given the fact that it was quite easy for other people to identify the person who's typing. They probably using that identification tag because it provided 'just enough' identification for immediate social contact. while still leaving vague enough to prevent social embarrassment and identification from a wider, unknown audience [Brignull and Rogers 2003, (5)].

- The Helsinki display in City-Centre : In parallel use, people can occupy an area of the screen and focus on their own task . They can work as a team by grouping with other users and focusing on the same set of objects.

  When people were using the display as a team, not all of them were on the display at the same time, but most of the group gathered behind the users, commenting and giving advices. Teamwork is also a way of dealing with physical obstacles, or it can be adopted because it is more fun that way, or both.

  An old woman was browsing the pictures. At some point, two men started using the screen on the left, which soon leaded into similar blow-up and overlap problem, preventing her from continuing. The problem of that kind of 'conflicts' were coming from the user interface. The users could unintentionally break the territorial borders where the users rotated, scaled the pictures. Those conflicts could also have positive consequences for the social organization at the display. Users were talking each other about the work

of the other people. They were making jokes and even laugh together. [Peltonen et al. 2008, (20)]

- The interactive advertisement system offers body interaction. Passers-by showed curiosity by moving their hands or moving to learn the interactivity. People called their friends to play with the colored silhouettes (the body frame were displayed on the screen) and interact together (see Figure 4.8)[Sahibzada et al. 2017, (25)]

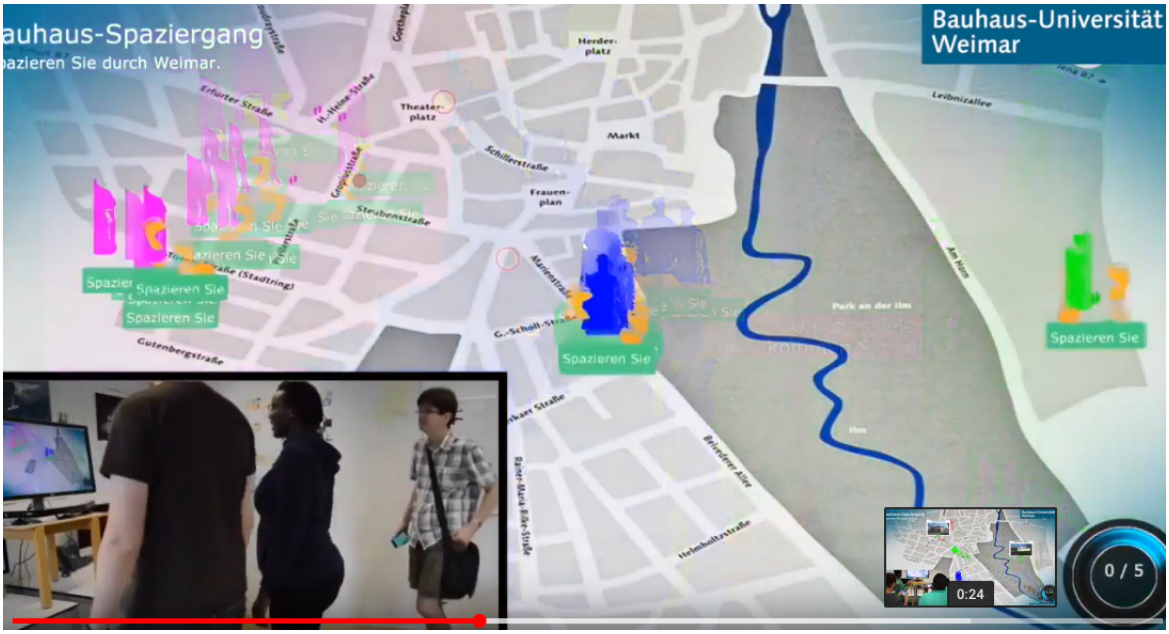

Figure 4.8: Multiple users with body interaction

- The Dynamo display provides interactive mechanisms to allow users to manage the shared use of the surface. It allows identified users to "carve off" a part of the large public surface providing them a workspace that they can use to arrange and share media. They can manage themselves the access to that region. Users mark an area of the screen by holding down the mouse and dragging to indicate the extent of a workspace. On release, interaction with the marked portion of the overall surface is restricted to the creator of the carved off region. The user can switch the control to another use by dragging the key to another one. Users are not required to identify themselves before using the system. Unidentified users are given a guest profile that provides access to public services and areas of the screen [Izadi et al. 2003, (13)]

- The two sided collaborative display : The implementation offers 2 sides, one

by user. One user can interact with the other one by touching the screen. Some of the items are for both users (like a color palette for example) and some are by user (like a check-box).

By default, the two users do see the same screen. One user can share information just by talking or flipping the item or a part of the screen (this way the user can have the letters in the right direction) and there is no need to replicate all info twice and loose some space on the screen (see Figure 4.9) [Li, Greenberg, and Sharlin 2017, (15)]

Figure 4.9: Same flipped screen for the users

- The tangible music interface : users can take any headphone or a tangible object. All people interact with the system together. Most of the time the system was used with more than one person at the same time (see Figure 4.10) [Xambó et al. 2017, (33)]

4.2.6 Combining Public and Personal Information

" *Rather than exclusively showing public information, when appropriate an active user can interact with personal information on the ambient display. With personal information it means information that one is not too concerned about others viewing – like free/busy time slots in a meeting calendar – as opposed to sensitive personal information like the body of an email* "[Vogel and Balakrishnan 2004, (31)]

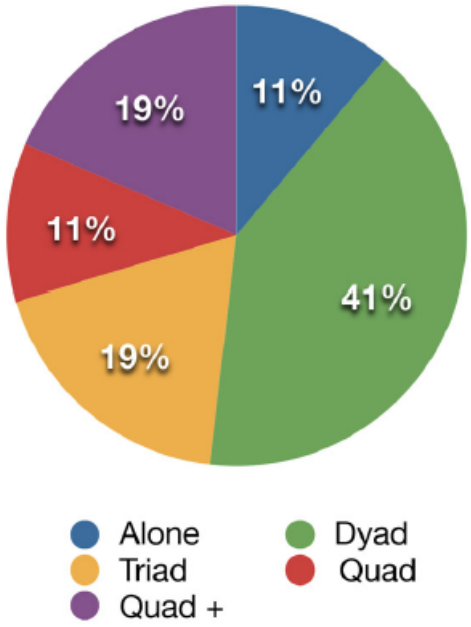

Figure 4.10: Percentage of group sizes

Examples

- The Dynamo system allows media to be packaged up into media parcels that can be left for others. Media parcels can be seen as containers that can encapsulate multiple media items. Parcels can be directed to one or more users of the system. A user who wishes to open a parcel needs to identify himself before having access to the information. In the case of users who access the surface through the base interaction points, the contents of the parcel are displayed as a box on the screen (see Figure 4.11)

  The most interesting thing in the system is the area reserved for a user and the way you can lock or hide information [Izadi et al. 2003, (13)]

- The two sided collaborative display defines some distinct territories. They could help to separate public and private information. Private information is not visible to the other user using an opaque color on the screen area. That specific territory is available at the bottom of the screen (see Figure 4.12)

  [Li, Greenberg, and Sharlin 2017, (15)]

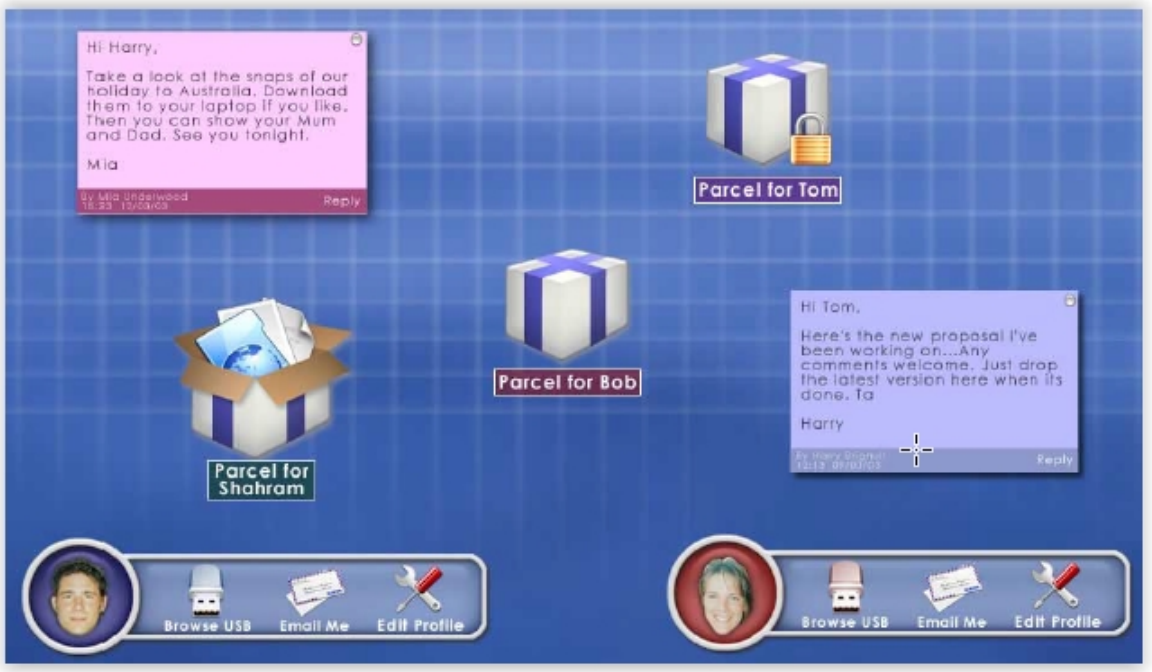

Figure 4.11: Dynamo parcels

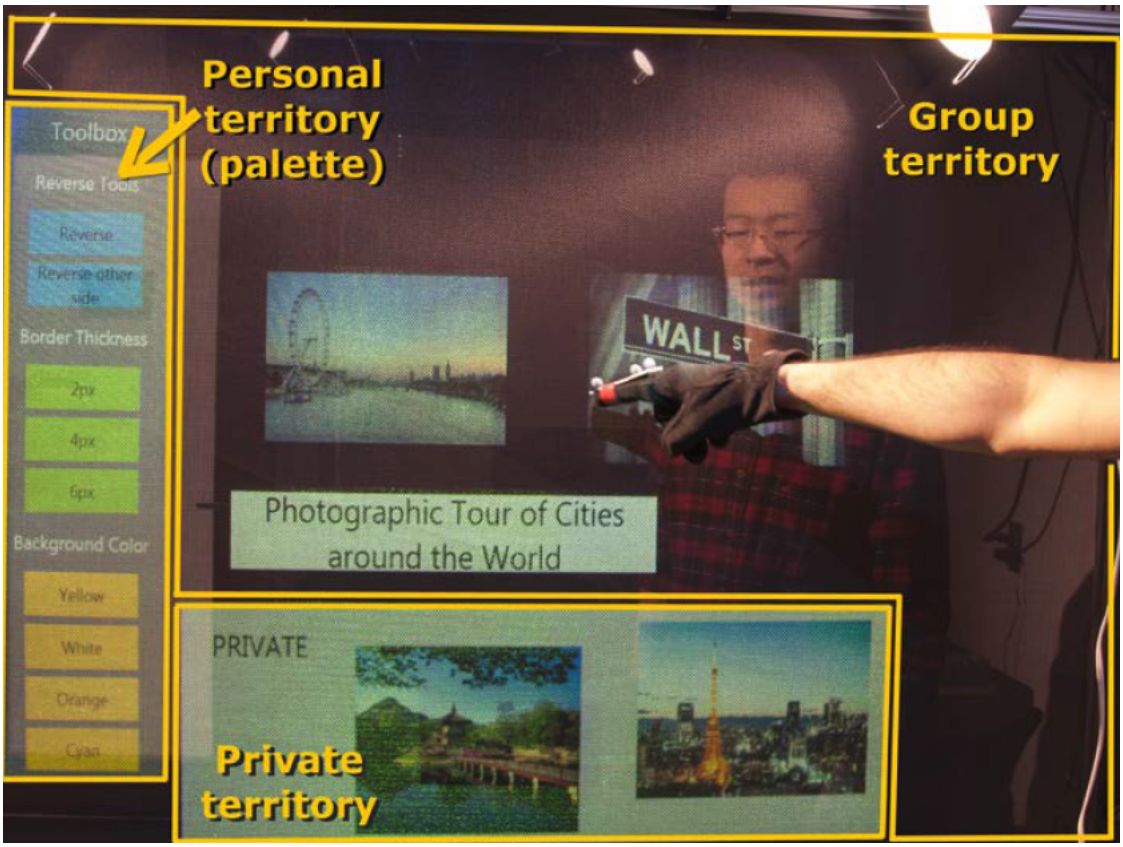

Figure 4.12: Areas for public and private data

4.2.7 Privacy

“ *a user should have an easy way to explicitly hide their notifications and minimize their implicit interaction* ”[Vogel and Balakrishnan 2004, (31)]

Examples

- The Dynamo system keeps the privacy by using the packages and security linked to it. The user makes a package and gives access or not to another user. The package can be opened or closed by touching the screen. [Izadi et al. 2003, (13)].
- The two sided collaborative display uses the territories, and the system is designed in a way that it is only used by two persons who are on each side of the screen. [Li, Greenberg, and Sharlin 2017, (15)].

4.3 Interaction Classification

Ardito [Ardito et al. 2015, (2)] reveals some more classification of displays in terms of interaction modality.

Many articles were analyzed and a classification was done using categories. The sum of the percentage may exceed 100% because a single paper can describe a system that have more than one feature.

Here are the percentage of paper for each category :

Interaction Modality	
Category	%
Touch	57
External device	34
Tangible object	21
Body	21

Classification of the examples according to Ardito :

- Display Setup
  - Vertical : Helsinki display, two sided collaborative display and interactive advertisement system

  - Horizontal : Dynamo and tangible music interface
  - Horizontal & vertical : The Opinionizer is vertical for the display and horizontal for the interaction

- Application Purpose
  - Social Interaction : Opinionizer
  - Entertainment : Helsinki Display and tangible music interface
  - Productivity : Dynamo and two sided collaborative

- Location
  - Conference : Opinionizer
  - City : Helsinki Display
  - Cultural Site : Interactive advertisement system and tangible music interface
  - Lab prototype : Dynamo and two sided collaborative display

- Interaction Modality
  - External device : Opinionizer, Dynamo
  - Touch : Helsinki Display and two sided collaborative display
  - Tangible object : tangible music interface
  - Body : interactive advertisement system

4.4 Design Challenge

The biggest design challenge is getting the first people to use the system and to activate the honey pot effect. Using a helper can instill confidence in people. One way of achieving this is to place the display near a traffic flow from which to draw a stream of people. Another obvious way is to offer free goods like food and beverages, and to put up posters and hand out flyers [Brignull and Rogers 2003, (5)].

Crossing this threshold requires a higher level of commitment from the participant. The form of the interaction needs to be very lightweight and visible from the offset. It should be easy to do and importantly not embarrassing to recover from

mistakes that are made. The interface needs to be clear enough for the people. So that they are reassured that their interaction with the display will be a low commitment activity, it will be quick and enjoyable [Brignull and Rogers 2003, (5)].

The Sahibzada interactive display confirmed that displaying the silhouette as a visual feedback for the users passing-by attracted attention, interest and provoked playful interaction [Sahibzada et al. 2017, (25)].

Chapter 5

Transitioning from Public to Personal

There are more and more displays available in public, semi-public and private spaces like airports, schools, offices and homes. Those displays can be used to display personal information securely and easily. With these links to our information, people may no longer have to carry around personal devices like tablets or laptops to access all their personal information.

But this has its challenges. How can a public display be effectively shared by several users for personal interactions while still providing some semblance of privacy to the individuals concerned ? What kind of input and interface technologies do we need to develop to allow effective interaction with large public displays ?

Vogel [Vogel and Balakrishnan 2004, (31)] worked on an ambient display on which people can interact and see private information, he identified interaction phases depending on the location of the user.

Brignull [Brignull and Rogers 2003, (5)] studied users interacting with large public display and identified three 'activity spaces'

- Peripheral awareness activities : In this activity space, people are aware of the display presence and don't know much about it
- Focal awareness activities : In this activity space, people are engaging and socializing activities associated with the display. They gave more attention and learn more about it
- Direct interaction activities : In this activity space, an individual (or a group) types in their opinion to the display

It appears that key bottlenecks occur when people have to make the transitions between the different activity spaces. In particular in crossing the threshold from peripheral to focal awareness activities; people need to be motivated.

Sahibzada [Sahibzada et al. 2017, (25)] studied the time spend by a user and his position used during the interaction. But no distance mesurement were done.

The phases of Brignull and the ones from Vogel are almost the same and newest articles use the same phases described here below.

5.1 Interaction phases

Different phases for interaction are analyzed according to the distance between the user and the display from distant implicit public to up-close explicit interaction (see Figure 5.1) [Vogel and Balakrishnan 2004, (31)].

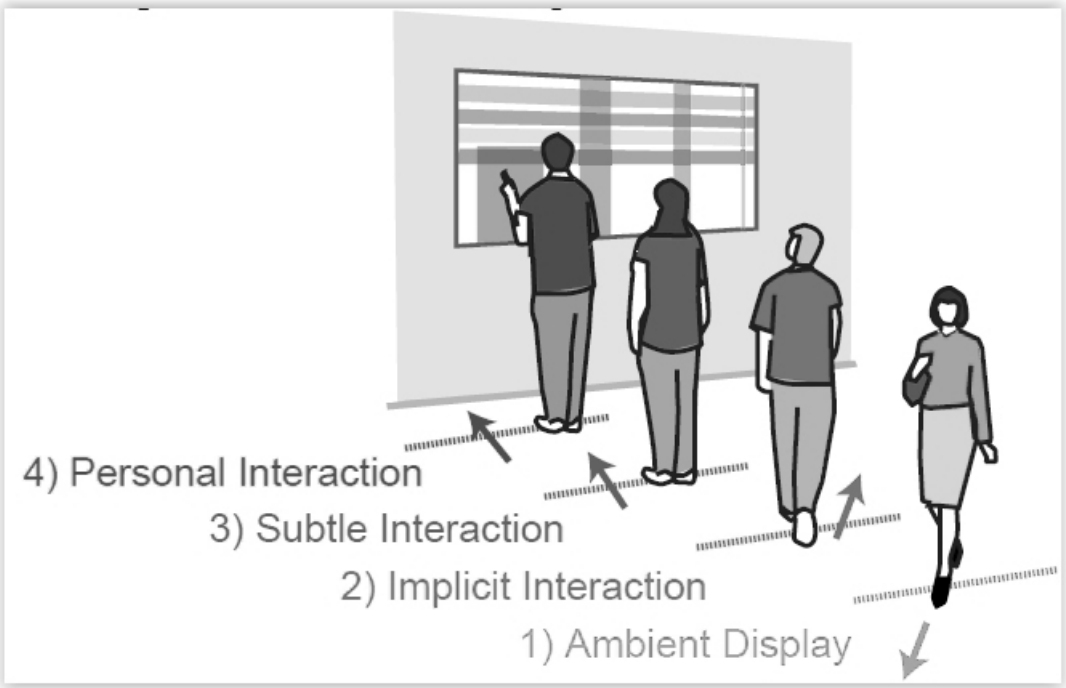

Figure 5.1: Interaction phases

- Ambient Display Phase : Neutral state of the display showing categorized information simultaneously with updates occurring slowly. The display will display all subsequent interaction so it is important that other phases don't radically alter or obscure it

- Implicit Interaction Phase : The system switches to that state when it detects that the user is open to communicate and subtly react by showing an abstract representation of the user on the screen. The user is notified subtly if there is an urgent personal or public information item that requires attention. This helps to draw the user closer to the display and lead him to enter to the next phase

- Subtle Interaction Phase : The user approaches and makes a pause. The user receives details information about the notification. The public data are augmented with personal information if it exists. This is a short phase (around one minute) to give the time to the user to select an information item and receive more details. The user uses simple hand gesture and explicit body movements to interact. The information shown in this phase can be personal but should be harmless.

- Personal Interaction Phase : The user can have more details on an information. A direct touch is needed to have an up-close interaction. The user is able to use his body for hiding his personal data from others. This phase is longer (2 to 5 minutes) and should be designed such that the disruption to the rest of the display is minimized and should allow multiple simultaneous users.

5.2 Transitions between phases

Users signals a phase change using implicit interaction such as body movement, body location and head orientation. " *They gradually become more explicit with gestures and touch. Phases should be entered and exited with minimal disturbance to the display but with enough feedback to the user so it is clear that a new phase began* "[Vogel and Balakrishnan 2004, (31)].

5.3 Supporting simultaneous phases for multiple users

Sharing a large display is done through time-based queuing or explicit space partitioning. The system should allow users to reach beyond their own spaces to access the information. " *Such interaction should not interfere with the fundamental role*

of the system as an ambient display that must remain useful for others at distance "[Vogel and Balakrishnan 2004, (31)].

5.4 Users feedback

The participants immediately understood that their body position was controlling the phases transitions.

Some phases were exited unexpectedly when the participants stepped back too far or turned their body too far. This caused them to become increasingly tentative in their movements since they didn't know exactly what the exit thresholds were. A visual indication of when a threshold is being approached would likely remedy this problem.

Identifying users needs to be done in that system. They proposed to make it a way that it doesn't require explicit sign-in/sign-out type actions. Identification of users may be done using active RFID tags, computer vision face recognition or active badges.

The system could be extended to allow collaboration between multiple users instead of just having separate interactions on the same display.

Chapter 6

Authentication

On most interactive displays a user can only see open data information, by definition those data aren't personal or private. On specific displays a user should be able to display and interact with his personal data. The display must verify that the person is authorized to see the information.

Contemporary user authentication schemes involve typing in username and password. When using a personal computer, typing in username and password is straightforward, but it poses substantial usability problems on ambient interfaces. Typing a username password combination to access his private data on an ambient display is not possible even more if the display is in vertical position.

"*Clearly, if the pattern of login and logout is not considered a usability problem today, it will most certainly become one in the years to come* "[Bardram, Kjær, and Pedersen 2003, (3)].

There is often an inherent trade-off between usability and security. User authentication mechanisms tend to be either secure, but less usable, or very usable, but less secure.

6.1 Proximity based login

Bardam, Kjær and Pedersen in their study [Bardram, Kjær, and Pedersen 2003, (3)] worked on a system which allows users to be authenticated on a device simply by approaching it physically. Before them there was the active badge system who could 'teleport' an X-Window session of a user when he moved from one display to another. The system has a lack of proper security mechanisms that can effectively ensure a secure user authentication. In case of theft of a token, or by recording and replaying the communication between the token and the reader, an adversary

can access the system and impersonate the legitimate user.

The goal is to find a system that could facilitate the authentication in an Hospital. A nurse, for example, can be authenticated on any computer but as she's moving all around in the hospital she needs to type 30 times her user, password combination. Because this was a highly cumbersome thing to do in a hectic environment, workarounds were established. For example, users would avoid logging out, enabling them to return to the PC without logging in later; passwords were shared among users and made very easy to remember ('1234' was the most used password at the hospital); and users would often hand over user sessions to one another, without proper logout and login. Hence, what was designed to be a secure system (with traditional username and password user authentication) was suddenly turned into a highly insecure system, because of obvious usability problems.

To solve that kind of issues they thought about using a personal pen for authentication and an active badge woven into their coat (not visible) revealing the user location to a context-awareness system. Using this, the user was authenticated securely with the pen and the display can automatically move the displayed information according to the user physical position in front of the display (see Figure 6.1).

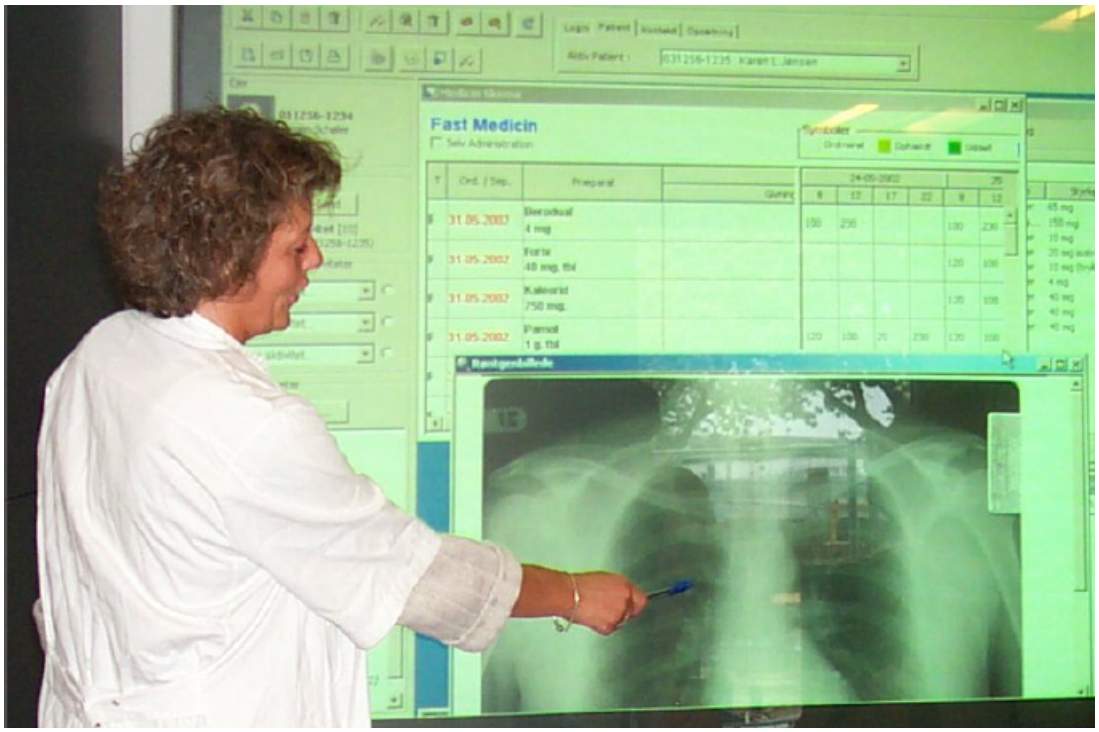

Figure 6.1: Doctor interacting securely with the display

As the personal token (the physical pen) is not secure enough as it is a RFID token, the authentication system was using a smart-card. The user puts the smart-card in a reader and types his username / password. They are recorded on the card as well as a secret key. Associated with that secret key, a public key is stored on the server. When the user changes from one computer to another, he puts the card in the reader, types his secret key and he's logged back in.

The system is secure because the user needs to have the smart-card in the reader and type his secret key or password to log on a computer all around in the hospital.

6.2 Biometric : Microsoft Kinect Identity

The Kinect Identity is how Kinect performs player identity recognition [Research 2016, (23)].

In this paper, the Kinect System from Microsoft uses a scan of the user with :

- 3D Depth Sensor
- RGB Camera
- Motorized Tilt

Identifying 3 Characteristics :

- Face

  The face detection extracts structural information of the user's face. examples : Boundaries of the eyes, nose and mouth.

- Clothes

  The Clothes are different from one user to another. Most of the time the user doesn't have the same color for trousers and t-shirt. The system separates human bodies from the RGB image using those color associations to identify the users.

- Body Skeleton

  The system uses the relative body height. The Kinect camera parses up and down the user and calculates the difference between the full height of the user and the height when the camera is at default position.

The Kinect uses image processing and machine learning technique to store and process all those information.

To identify a user, Kinect uses the scanned characteristics and compares them to the stored ones and do a match.

Scanned User Characteristics	Known User #1	Known User #2	Known User #3	Known User #4
Face	-	+	+	U
Clothes	U	U	-	-
Body	+	+	U	U

Legend :

+	Positive match
U	Unknown
-	Negative match

As the known user and the scanned user have 2 positive matches, and at the same time the other ones do have maximum one positive, the user is identified as the #2.

6.3 Biometric : Carpus

Carpus identifies users by observing their hands with a hi-res camera. Each user registers with the system by providing samples of their two hands. To make an easier registration, the user follows specific drawings on the table while the camera extracts grained details from the back of the hands (fingers are excluded from the region) [Ramakers et al. 2012, (22)].

Steps to identify people :

- Scan without fingers (see Figure 6.2)
- Extract grained details from the scan (see Figure 6.3)
- The system stores that information in a database and can uniquely identify each hand (see Figure 6.4)

Carpus identifies a hand when it touches the display. That way, multiple users can interact at the same time while keeping different activities for each hand.

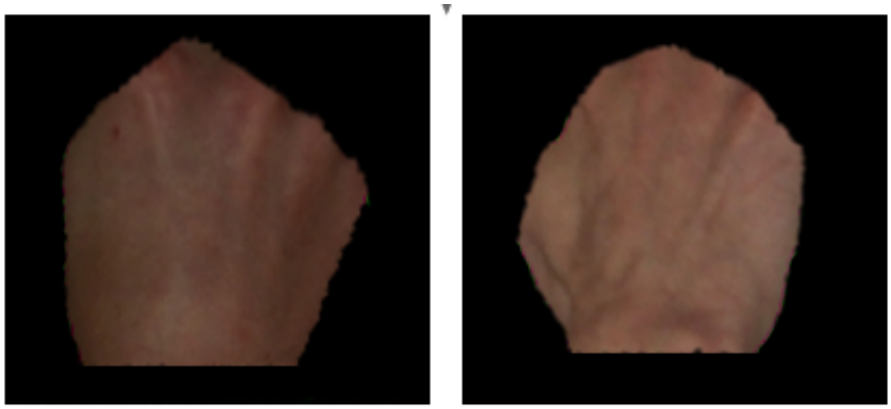

Figure 6.2: Scan without fingers

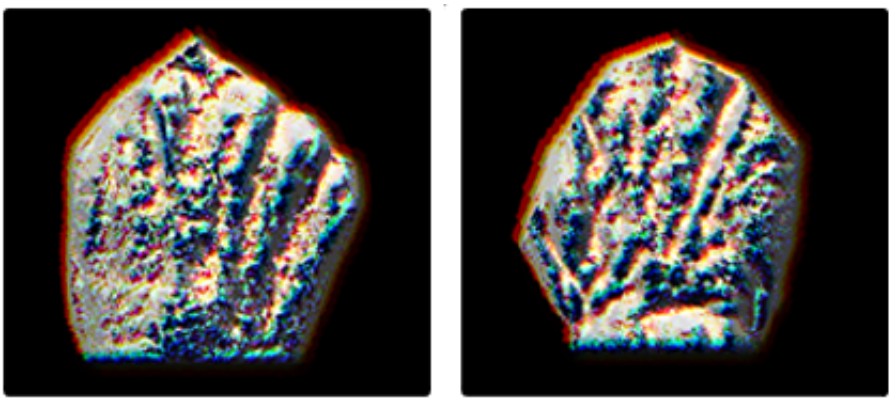

Figure 6.3: Extract grained details from the scan

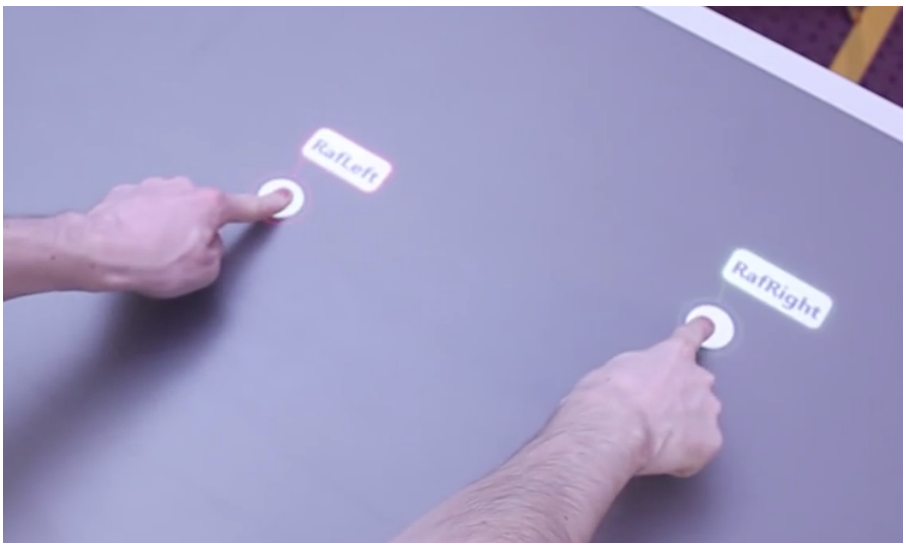

Figure 6.4: Store information in database to identify each hand

Examples :

Selecting a color with one hand and drawing in that color. Selecting another

color with another hand and drawing using the selected color. Carpus permits to draw with multiple hands and each hand will draw in the latest selected color.

Carpus can be useful in a store environment to have information about products : a phone can have a specific drawing on his face (that is known as an item by Carpus) with linked information like specifications, type of product and display them when the item is on the display. The user can now point the display to see that information or find other products of the same type and compare the models. Carpus offers to save the status of the display by user. When the phone is no more on the display, all info will be hidden and when the phone and the user will be identified (use the phone on the display and identify the user by touching the display) the last session is restored.

6.4 Mobile Phone Role Authentication

As many people do have a smart-phone, it can be a good way to use it as an authentication device on public displays. Schöning, Rohs and Krüger [Schöning, Rohs, and Krüger 2008, (26)] initiate that kind of reflection by implementing this using roles. They addressed the problem that in some collaborative work situations, the group of users of a multi-touch wall varies greatly in competence, hierarchical level, and decision-making authority, demanding a dedicated authentication and access mechanism for small regions of a multi-touch surface.

The system uses a personal mobile device with multi-touch surfaces by using the device to authenticate and interact with the display. The authentication is done using Bluetooth technology and the light from the camera of the device. The user who wants to access secure data will use his mobile device to touch the display area with the link to the data. The mobile device will send a light flash to indicate the region the user wants to interact with and at the same time initializes the authentication process via Bluetooth. The system receives the position of the display to interact with, verifies if the user id has access to the data. If so, it sends the answer through Bluetooth and the action is executed.

The main goal is to ensure that critical information are only executed by authorized users. The authentication system has to check the identity as well as the input position of the user who attempts the operation. The system should allow for easy and spontaneous authentication without requiring too much effort and without interfering with other simultaneous users who perform non-critical operations (see Figure 6.5).

Figure 6.5: Use the telephone to authenticate the role

Chapter 7

Comparing all authentication and interaction systems

7.1 Needed properties

Here is a list of identified properties needed for an ambient display which can provide public and private data.

- Security : The private data are accessible through a secure system
- Privacy : The private data are displayed 'hidden' from other people (when leaving the screen or during concurrent usage)
- Attractiveness : People must see they can interact with the display
- Usability : People doesn't need to search how the display works
- Public access : Display is located where people are passing-by

7.2 Application of the properties on all presented systems

- Dynamo
  - Security : Done through a user - password combination
  - Privacy : Kept through the locking system
  - Attractiveness : None, it is a collaborative system and the users know how to use it

  - Usability : Good but still needs keyboard / mouse
  - Public access : No forecast for that

- Vogel's Interactive Display with personal data
  - Security : Not implemented (explained in future works)
  - Privacy : Done by interaction phases
  - Attractiveness : Good through interaction phases
  - Usability : 'old' system so not very attractive in layout and colors
  - Public access : Good as it takes care of private data not overlapping too much for public ones

- Two Sided Collaborative display
  - Security : None
  - Privacy : Kept through the masking of information
  - Attractiveness : None, it is a collaborative system and the users know how to use it
  - Usability : Good, like a smart-phone
  - Public access : No forecast for that

- The interactive advertisement system
  - Security : None
  - Privacy : None as it is public information
  - Attractiveness : Showing the body position to attract the attention
  - Usability : Good using the user's body
  - Public access : Already in a public place : tourism information place

- Proximity based login
  - Security : High
  - Privacy : High (linked to security)
  - Attractiveness : Good as it can be extended outside of an hospital
  - Usability : Good as it takes 2 minutes to explain how to use the card reader

  - Public access : Not possible because of the system hardware needed

- Kinect Identity
  - Security : Good recognition and analysis (but not perfect if twins are dressed the same, what's happening ?)
  - Privacy : Not much as the screen is for one user only or for games with multiple users
  - Attractiveness : Enjoyable authentication method and hardware was bought by the user
  - Usability : Good, easy to understand, the user just need to be in the front of the system
  - Public access : Not that much as the user needs to record his data first and the system is limited in terms of concurrent users

- Carpus
  - Security : Good biometrics measure
  - Privacy : No, everyone see all screen all the time
  - Attractiveness : Good if the display invites the user to touch the screen
  - Usability : Good but need to be on a table
  - Public access : Any data is displayed in 'clear'. Users need to register first. The display is in horizontal position and according to Ardito [Ardito et al. 2015, (2)] that position is not good for cities

- Mobile Phone linked to role
  - Security : Good, authentication is done using a token located in a physical device
  - Privacy : Not that good as it displays information on the screen without any hiding system, although it needs to be done by an authorized user
  - Attractiveness : Good, many buttons displayed
  - Usability : Good, it just displays areas and buttons on a touch screen
  - Public access : Display default information for everyone

7.3 Comparison conclusion

Any of those systems can have all the topics covered.

All those authentication systems are in controlled environment (inside an hospital, at home, at work) or propose open data only. The following study tries to extend the interaction and authentication system to an ambient display that can be used in a city, displaying private data securely and maintaining privacy.

Chapter 8

Use case

As part of displaying information, the goal is to implement an ambient display inside the university. As the ambient display is a user interface, the methodology from the UX Book [Hartson and Pyla 2012, (10)] was chosen. It consists of cycles with 4 steps : Analysis, Design, Implementation and Evaluations (see Figure 8.1).

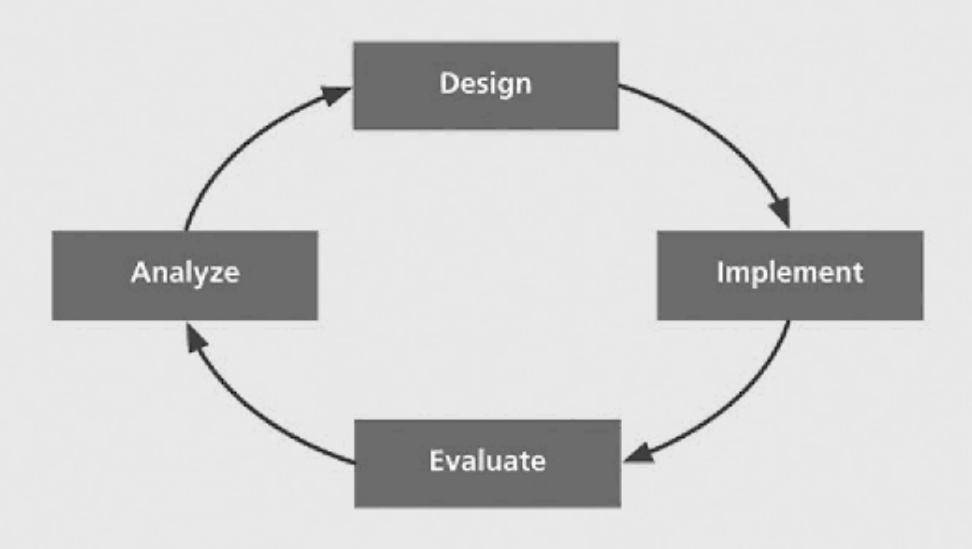

Figure 8.1: process to design user Interface

8.1 Analysis

Following the characteristics of an ambient display the data must be situated, informative and functional. The analysis determined that a good use case will be an electronic information board.

On a daily basis, many students and teachers look at the current information board located in the university. The board is in paper format and contains information about conferences, general information, menu from the restaurant of the university and so on. The board in the faculty of computer science is located on the second floor, if the board is replaced by an electronic one, the faculty can even install many of them: one or many by floor, one in the teacher room, and so on.

According to the potential spread of display locations, an implementation of a web site is the best choice. Any smart tv do have an integrated browser or any small computer device can browse and display the site on a monitor or a 'non-smart' tv.

Today the data already follow the characteristics :

- Situated : Contextual and Local : Information are from the faculty of computer science or from the university of Namur
- Informative : Consistent and insightful : Posters of conferences, Evaluation schedules, Internal notes
- Functional : Trustworthy (maintained by the secretariat) and Participative : Conference

An electronic version of the board is more flexible and authorizes some automatic updates of displayed information. Not all students do have access all the time to their university mailbox. Secretaries communicate through that network all changes that can happen :

- Room changes
- Schedule changes

The electronic board can display those information in real time, as they are available in the ADE Web Direct planning (ADE) [Unamur 2018, (28)]. The ADE is a website displaying all schedules of courses of the University of Namur (see Figure 8.2). The ADE is maintained by secretaries so the data are always up to date.

Displaying the ADE follows the characteristics as it is information of the faculty. Information about schedules and currently running courses. The data are maintained by the secretariat in real-time.

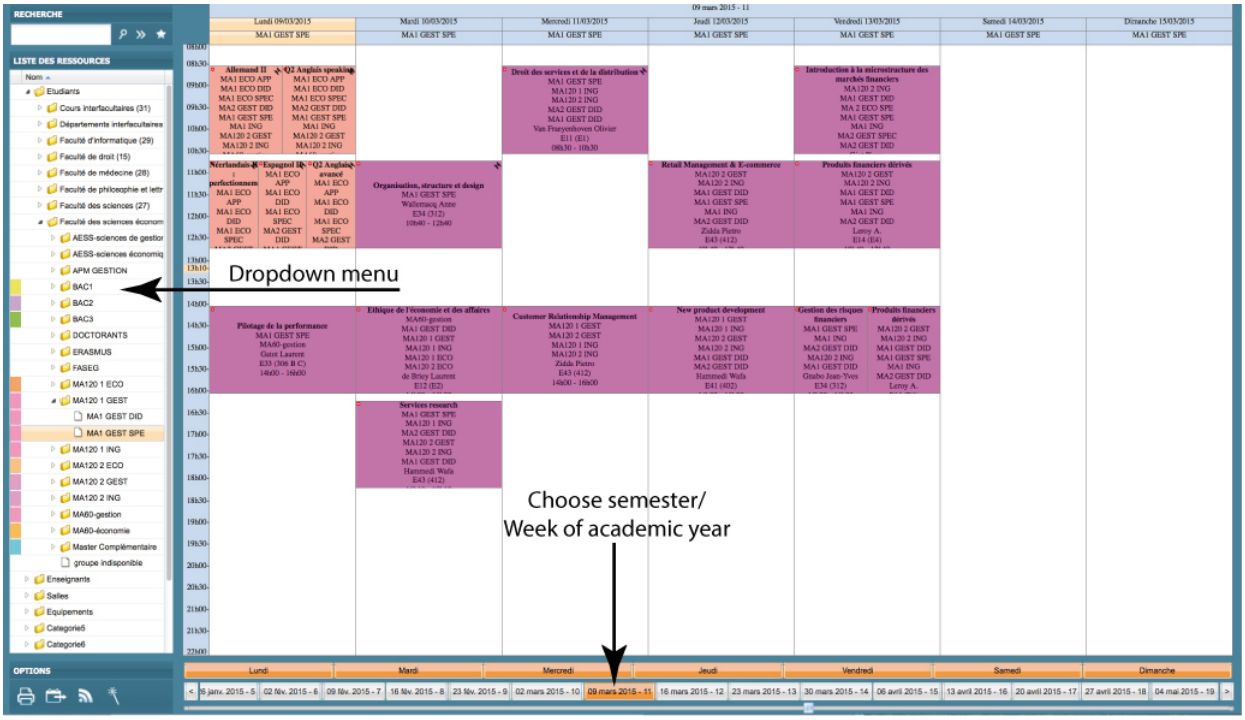

Figure 8.2: ADE Web Direct planning

The availability of the secretariat (located on the second floor of the faculty) can be displayed. This way, a user on the fourth floor can see if there is someone available without going downstairs.

To facilitate the room location in the building, the board can display a map of the floors. This can permit to a new student, or a student from another faculty, to be aware of the changes and locate easily a room in the faculty.

Displaying the map follows also the characteristics as it is the floors of the faculty and it is coming from a trusted source : the faculty building fire evacuation plan.

Actually the news (general information) are in paper format so maintenance need to be done manually. Changing this by a news feed is easier to maintain.

The menu of the university restaurant is also a good information for students and teachers, they can check the menu before moving to the restaurant and this way avoid having bottlenecks with all people just checking the menu at the entrance. The menu is actually available in a digital pdf format.

8.2 Design

According to the methodology, a prototype of design was done manually using paper. That kind of design allows to be easily changeable and the persons who's making their comments understand that it will not be a huge work to change something. They also understand that it will not be the final result.

The first drawing shows the base status which means all information without dynamic courses updates (see Figure 8.3).

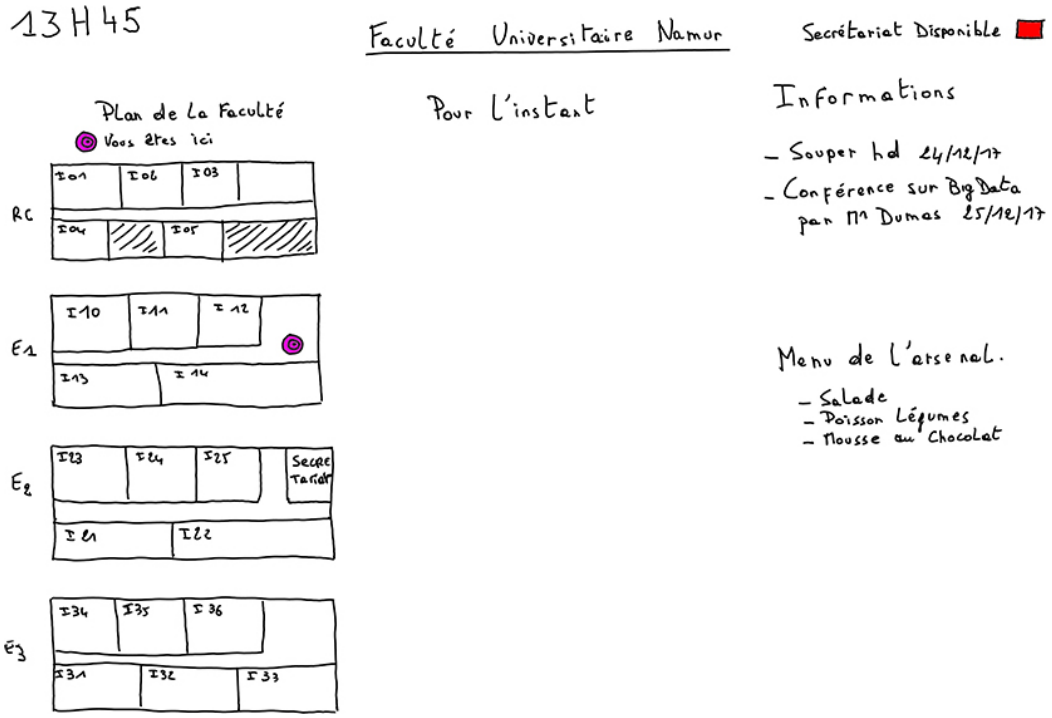

Figure 8.3: Default without dynamic data

The second drawing shows current dynamic courses list automatically updated (see Figure 8.4).

8.2.1 Design principles

The proposed prototype follows the design principles :

- Calm Aesthetics : The displays will be in the faculty. The aesthetics will be cleaned as much as possible with all sections clearly separated and identifiable
- Comprehension : The users will see the list of current courses, the news list and the menu of the restaurant. All those information are directly understandable for them

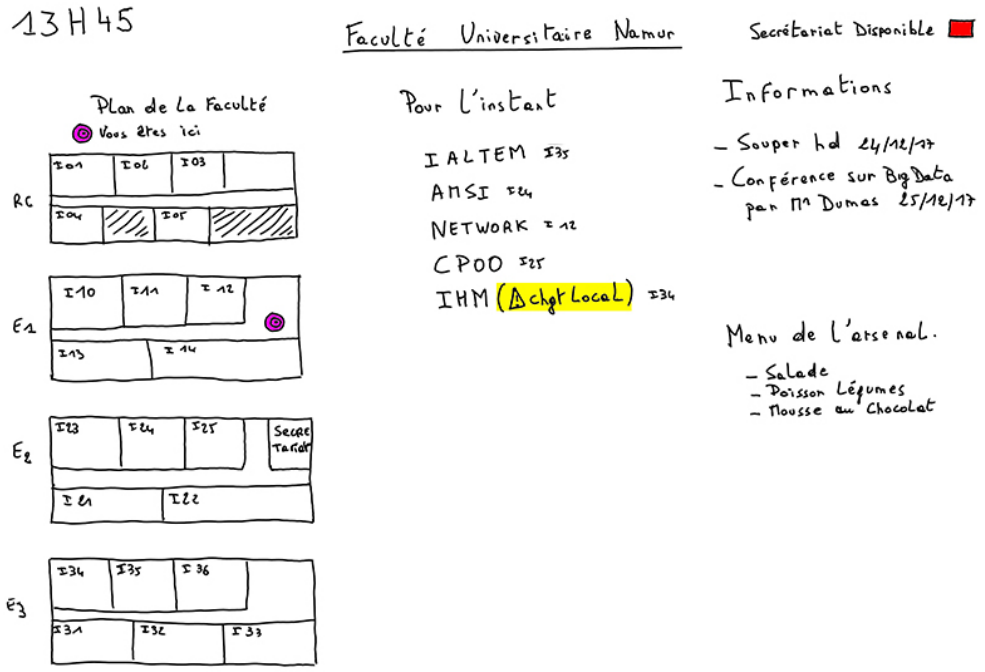

Figure 8.4: Board with dynamic data

- Notification : The list of news and the list of current courses will be updated so the screen will change automatically
- Immediate Usability : No training is needed to understand the information as they are clearly identified. Some of the information are already available in paper format on the current information board. At this stage no interaction is proposed
- Shared Use : Not applicable as at this stage no interaction is proposed
- Combining Public and Personal Information: All information like courses are public and news are more private information as they are by faculty
- Privacy : Not applicable as at this stage no interaction is proposed

8.3 Design Evaluation

Showing the classroom number just next to the course is not visible from a long distance from the board. A better way will be to color the classroom on the map using the same color as the course in the list. With the usage of colors it is easy

for the user to locate the course and the physical room linked to it. The user can identify easily any room change (displayed after the course name) or a course taking part in another building (no color and external text).

8.4 Design - 2

The design is updated with the result of the evaluation by adding colors for the match between courses and classroom location on the map (see Figure 8.5).

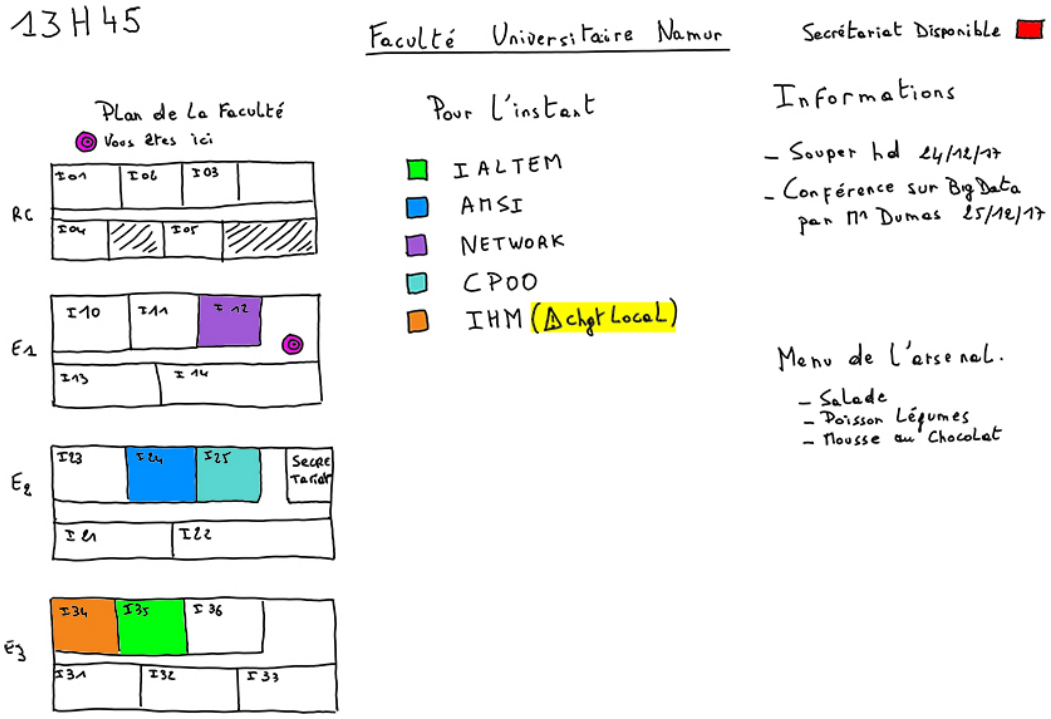

Figure 8.5: Board with dynamic data

The new design raises up the level of comprehension and notification from the design principles.

8.5 Implement

As seen during the master courses, even if this is a prototype, the development is made with thinking about those recommendations :

- Re-usability : A maximum of parameters will be in configuration files (so it can be portable easily to another faculty)

- Modifiability : Code will be structured and splited into different files according to their purpose
- Generalization : As it is in javascript it can be executed on any web client and server

This iteration of implementation covers these topics :

- Building map : digital vector file is available
- Update of courses list from ADE automatically
- Color the room using the building map

As it is a prototype, the goal was to make it simple. According to the scope, there is no need to have an application server. The chosen language for development is javascript. In that language many libraries exist (like JSON file reading) and manipulation of digital vector files is available in standard.

There is only one configuration file (in JSON format) for all parameters :

- mapClassName : the class name used in the map for defining the room
- facultyName : the name of the faculty. Example “d’informatique”
- mapRefreshRateInMilliSeconds : number of milliseconds to refresh the map
- mapClassLength : number of caracters defining a room
- mapClassExternalText : text that needs to be added the course if the room is not found on the map
- mapNbMinutesForDisplayCourse : number of minutes to display the course.

  Example : 30

  - The course finishing in 30 minutes or less will not be displayed
  - The course starting in 30 minutes or less will be displayed

According to the modifiability all parts of the screen are in separated files :

- index.html : titles and multiple frames : one by other file
- map.html : building map and courses list

The page shows the map and courses linked with colors according to the design (see Figure 8.6).

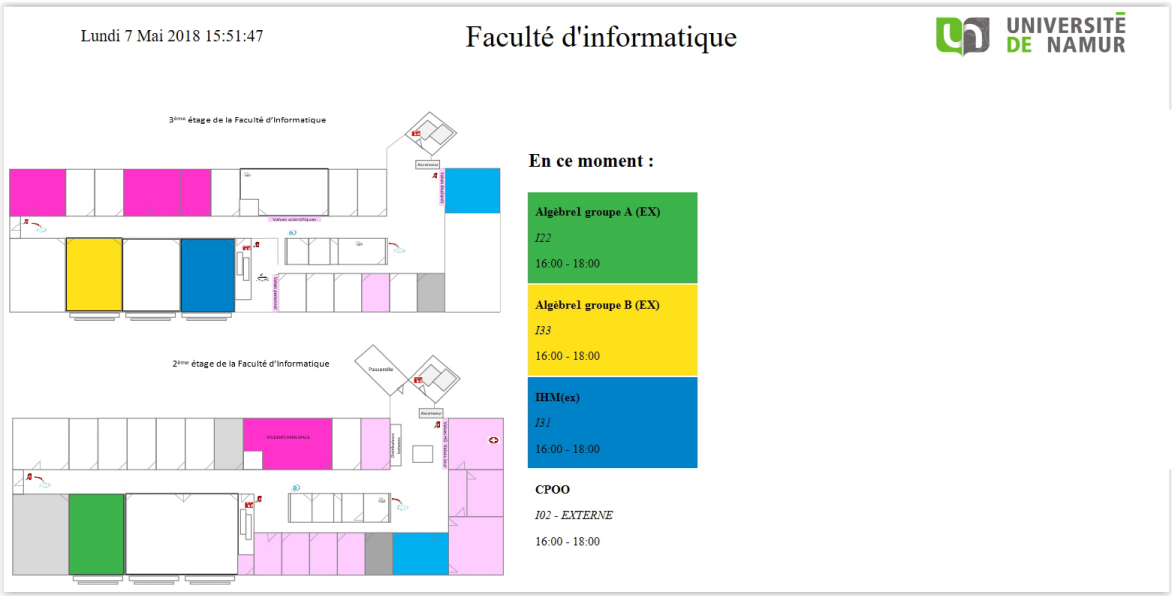

Figure 8.6: Electronic Board

8.5.1 Map Update

The map of the faculty is available in digital vector format : svg. Javascript has standard svg manipulation.

The map file has been updated with some rectangles to limit the rooms where the courses can be given. Those rectangles must be in line with the following requirements :

- Class attribute must be the same as the mapClassName parameter in the configuration file
- Id attribute must be the classroom identification number. Example : I32

According to those requirements, the mapping between The ADE schedule and the map is done.

The ADE is downloaded in an ics format (done by a cron on the server and saved in the website directory). A library [Saggs 2012, (24)] was used to convert the ics to JSON as the JSON can be directly treated in javascript.

Using the extracted schedule, the items are filtered according to their start and stop time and the current time.

A list with the filtered courses is displayed on the right of the map. The corresponding room is filled with a unique color if the classroom is available on the map. The course in the list is filled with the same color. That way, the user can do the mapping fast and accurately.

The update of the map page occurs each milliseconds specified in the configuration file.

8.6 Evaluation

The first part was evaluated by three people (Mister Dumas, Mister Clarinval and myself). At this stage, as it is a part of development, it is enough.

So now those additional features would be implemented :

- News : update will be done by secretaries (as it is done today)
- Menu : available in digital pdf format
- Secretariat availability : usage of a tangible interface in the secretariat can update the status and the color

In this use case, the reading of the pdf menu will not be implemented. Nevertheless it is a good perspective for future extension.

The Secretariat availability must be evaluated by the secretaries because they can see it as a watcher of their work. The feature will not be implemented but it is a good perspective for future implementation.

8.7 Implement - 2

This iteration of implementation covers these topics :

- News : update will be done by secretaries (as it is done today)

To manage the news, the configuration was extended with that value :

- newsRefreshRateInMilliSeconds : number of milliseconds to refresh the news

A frame was added in the index.html :

- news.html : display the news list

The news aren't available in digital format today so the news feed was stored as a json file on the server. That file will be maintained by the secretaries. As making a modification of a file on the server side is not available in javascript, a web page was developed to do it : '/Editor/newsEditor.html '. That page uses the javascript json editor [Jong 2017, (14)] (see Figure 8.7):

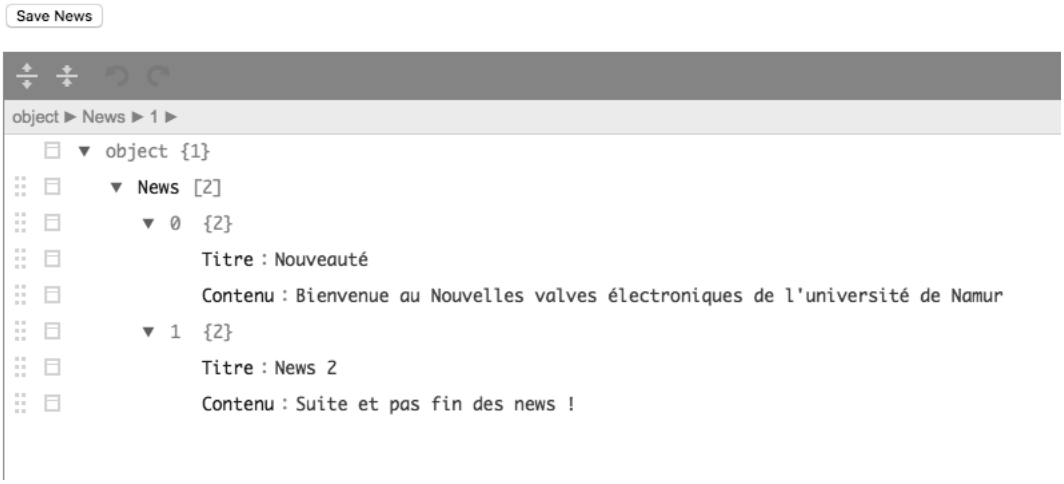

Figure 8.7: News file editor

As Javascript is running on the client side, the modified news json file is downloaded locally on the computer (by clicking on the Save News button) and then uploaded using a secure ftp (File Transfert protocol) connection to the server (secured by a user-name and password).

The update of the news page occurs each milliseconds specified in the configuration file.

8.8 Evaluation - 2

To evaluate the implementation, a screen can be installed just next to existing board. That location is great as the users already passing by an check regularly the current board.

The evaluation will be empirical and rapid :

- Empirical : many people will evaluate it
- Rapid : demonstration of design concept, speed and cost saving

Methods to receive evaluation results :

- Paper questionnaire next to the screen and a box to post them
- A link to an on-line questionnaire (see example with Figure 8.8)

All answers will be classified and analyzed to modify the implementation.

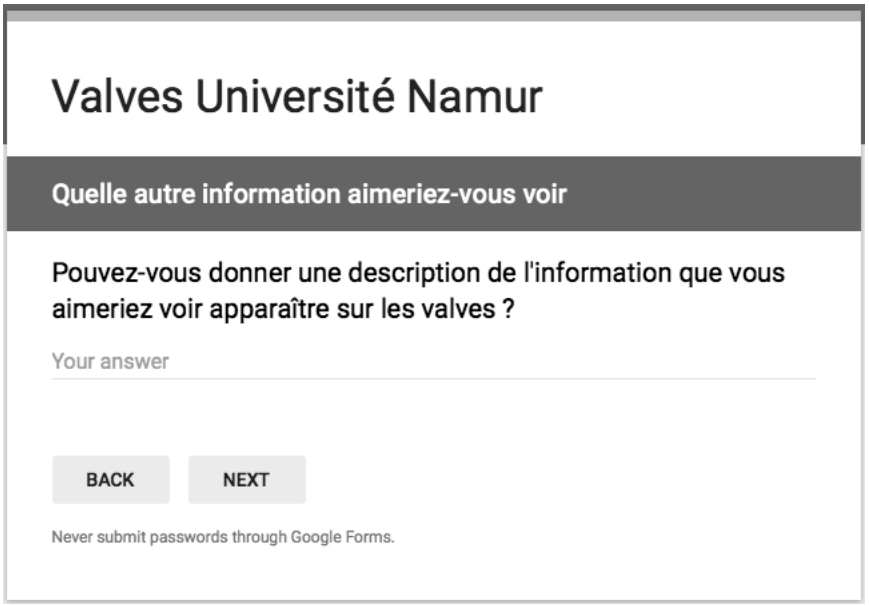

Figure 8.8: News file editor

8.9 Remarks & Observations

Javascript was used to implement the solution but that language is not in line with the master courses recommendations. It is not a structured language with objects and classes. The variables are not type defined. A function can be a parameter of another function and the code of the function's parameter can be written inside the call. Nevertheless the language is easy to learn and we can have results quite fast.

Chapter 9

Study

The study will try to provide some tracks to build a system who will cover all the previously identified topics :

- Security : Uses encrypted token stored in a physical device
- Privacy : Personal Information is hidden by default and will be hidden automatically according to the user position
- Attractiveness : Shows to people that they can interact with the system
- Usability : Use people's current habits to use smart-phone application
- Public access : Displays default information for everyone with dynamic updates

As seen in this document it is also important to :

- Display local data

The study will investigate how to add interaction and authentication to the use case. Interacting with the electronic information board can be interesting : consulting e-mails, getting information about their personal schedule, and so on.

The authentication system should be straight forward and convenient for the students, while taking care of the privacy of personal information displayed.

The study is focused on the implementation in a university but according to the re-usability recommendation, it must be portable to allow interaction and privacy in the cities.

9.1 Reflection steps

The study does not include the prototype. So the methodology used is the same as for the use case but without the prototype step. Evaluations will be done directly on the design.

9.2 Analysis

The analysis must answer the following questions :

- Which useful private data the display can show ?
- How the users access securely to those data ?
- How the display will take care of privacy for the user ?

9.3 Design

This design step will cover the first question : Which useful private data the display can show ?

In the University of Namur, the communication between secretariat and students is done through the BVE (Bureau Virtuel de l'Etudiant). The BVE is accessible using a website. It contains all needed information for the student : link to all communications, e-mails, exams results, and so on (see Figure 9.1).

Accessing to those data with the ambient display is useful for the students. All those data are already available in digital format.

9.4 Design Evaluation

The data are interesting for the student.

9.5 Design - 2

This design step will cover the second question : How the users access securely to those data ?

This raises a new question :

- How the user authenticates on the system ?

Figure 9.1: Virtual desktop of a student

9.6 Analysis - 2

The user needs to identify himself on the display before accessing his private data.

Each student owns a student card. Most of them have always that card in their wallet. Changing the card to an RFID (radio frequency identification) one can be a good solution. According to the re-usability recommendation, it will not be possible to transpose the RFID card to cities : too many constraints in terms of manufacturing and logistics. Furthermore people will not add a card in their wallet to interact with the display. They will eventually think about going to a desk to catch one, but only when they are in front of the display. Ten minutes later they will forget it.

All students own a smart-phone, it is a good device which can provide a secure access to a system. All people in cities, who can have interest to interact with a display, also own a smart-phone. People who don't own a smart-phone will not find any interest in interaction with an ambient display.

Using a smart device (phone or tablet) raises 2 parts for the design :

- How to register on the display ?
- How to be identified on the display and have access to the private data ?

9.7 Design - 3

This design step will cover the first raised question : How to register on the display?

According to the design challenges of a display, the user must see that he can interact with the display. A reserved area of the display provides this. With the choice of smart-phones (or tablets) to access the interaction part of the display, a QR (Quick Response) code is displayed and drives the user through the registration process (see Figure 9.2) :

1. Scan the QR Code
2. Download the application from the store
3. Register on the server
4. The token creation and download step will be done in background and hidden for the user

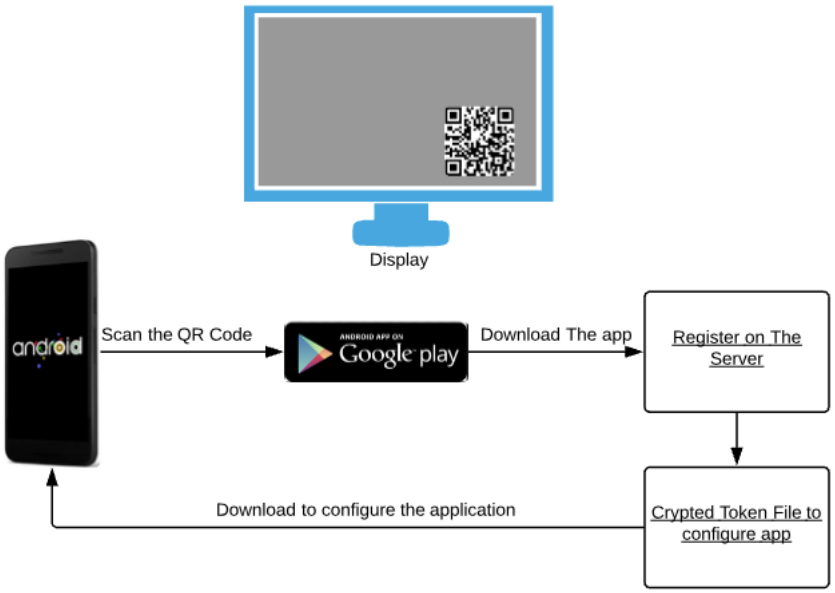

Figure 9.2: Registration work-flow

The server registration uses a user-name password combination.

The token will be unique on the server (GUID for example) and will be encrypted and stored on the server side. The server will keep the link between the token and the user-name. A copy of the token will be stored securely on the device and will be used for future authentication.

9.8 Design Evaluation - 2

The process of registration is usual for users who own a smart-device and register on on-line applications. In the application, an information about security must be showed to the user, this way he will have confidence in the security of the system.

9.9 Design - 4

This design step will cover the second raised question : How to be identified on the display and have access to the private data ?

After registration, the system should communicate with the token located on the smart-phone. That communication must be done through a straight forward system. The actual smart-phones do have wireless protocol : NFC (Near Field Communication), according to Haselsteiner [Haselsteiner and Breitfuß 2006, (11)] the system can be used as a contactless token : NFC is used to transfer wirelessly data between two devices.

The usage of the NFC forces to install an NFC zone on the display. That design can be part of a future perspective.

When the user wants to identify himself on the display (see Figure 9.3) :

1. Disposes the smart-phone to the identified NFC zone
2. The server searches the user corresponding to the token in the database (step done in background and hidden for the user)
3. If the user is known by the system, the interaction with his private data starts

9.10 Design Evaluation - 3

As for the previous evaluation, that layout can be used as well in cities and the authentication step is fast and easy for the user. The system constrains the user to wear his smart-device to interact with the system.

The previous designs cover the first two steps of the analysis :

- Which useful private data the display can show ?
- How the users access securely to those data ?

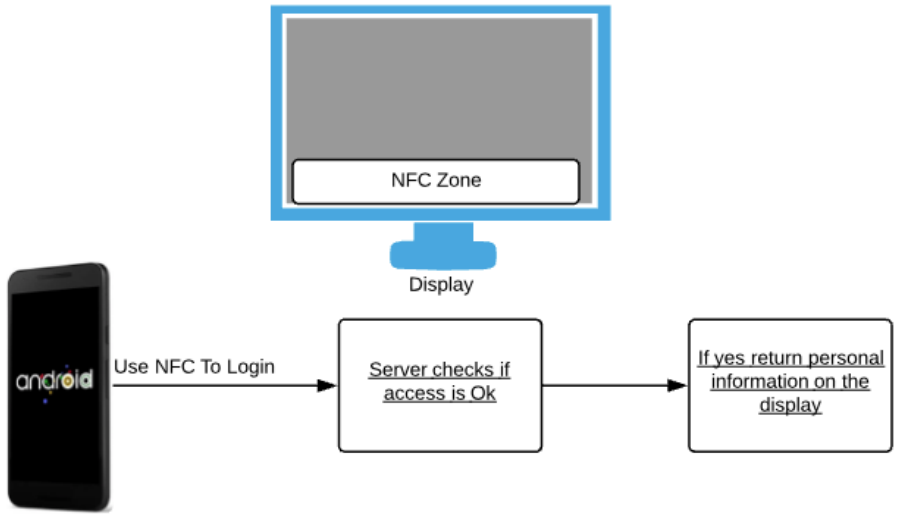

Figure 9.3: Authentication work-flow

Next step will be to design the third step : How the display will take care of privacy for the user ?

9.11 Design - 5

This design uses two characteristics :

- Interaction phases : check the user's position and change the display of private information accordingly
- Simultaneous usage : be sure that the other people can't see the data when interacting together

The display of personal data will only take part in the Personal Interaction Phase : when the user can touch the display to interact.

After a successful login (using his smart-phone) the system switch to interaction phase :

1. An hidden area shows up with an un-hide button
2. The user can resize the private area
3. The user touches on the un-hide button to interact with data
4. When done, the user closes the area

Remarks :

- The personal area must have a maximum size : by recommendations, a private area can't affect the first purpose of the display : show public data
- The user must have confidence in the system and be sure that his privacy is kept :
  - To track the user and re-identifying people a group made some test with RGB camera [Hernandez, Castrillon, and Lorenzo 2011, (12)]. The system can track people and re-identify them if needed. In our case re-identifying is not necessary. The user can just re-identify himself using the NFC.

    Using the tracking system, areas of interaction phases can be defined and can automatically hide private data if needed. Using an RGB camera situated on top of the display filming people from above, permits to detect any leave or remoteness from the user.
  - Data will be automatically hidden if the user turn too far his head or his shoulders
  - Closing the private data area forces a log-off of the user
  - If another people tried to un-hide the data, the RGB camera can detect that the request is not coming from the authenticated user. The system blocks the un-hide action and automatically log-off the user so he will be aware that something was going wrong.

9.12 Design Evaluation - 4

Privacy of data is respected. At the time of implementation the proposal should be modified according to the physical factors and tests done.

Interaction between users is not proposed on this stage. The interaction is based on displaying data and interact to retrieve public or personal information and not exchanging data between users. But this can be a perspective for future works.

In this study the focus is only on the software part of the system. The security of the infrastructure is a good perspective for future works like : network, physical display, hackers protection, and so on.

9.12.1 Design principles

The proposed design adds interaction and authentication, by this it follows the design principles :

- Calm Aesthetics : The displays will be in the faculty. The aesthetics will be clean as possible with all sections clearly separated and identifiable
- Comprehension : The users will see the list of current courses, the news list and the menu of the restaurant. All those information are directly understandable for them
- Notification : The list of news and the list of current courses will be updated so the screen will change automatically
- Immediate Usability : No training is needed to understand the information as they are clearly identified. Some of the information are already available in paper format on the current information board
- Shared Use : propose multi users at the same time but without interaction between them
- Combining Public and Personal Information: All information like courses are public and news are more private information as they are by faculty. The interaction adds personal information from the BVE
- Privacy : Usage of areas and auto-hide and auto-close keeps privacy of personal data

Chapter 10

Conclusion and perspectives

Ambient displays aren't new, the ambientROOM is the right example : it shows that people need to be connected and receive information from the external world.

The analysis of public display (Bicycle counter in Copenhagen, CitiWall in Helsinki, The Tidy Street Project, the nuage vert and the display of private data in a street of Sydney) was done according to the following characteristics :

- Situated : embedded in the real-world
- Informative : data aren't as posters and public advertising
- Functional : data are relevant for people (trusted local data) and not disturbing in their environment

Display information is interesting but local data can be manipulated by the users and offers interaction. Interaction is not easy and the honey pot effect plays a great role : the more people uses the display, the more people will also use the display.

An analysis of some interactive displays (The Opinionizer, the Helsinki display in City-Centre, the interactive advertisement system, the Dynamo, the two sided collaborative display and the tangible music interface) was done using the design principles :

- Calm Aesthetics : local data displayed in an aesthetic way
- Comprehension : users must understand directly the data
- Notification : users are able to identify updates
- Immediate Usability : users don't need training to use the display

- Shared Use : multiple users can interact and/or share information
- Combining Public and Personal Information
- Privacy : keep personal data hidden from other people

Ardito [Ardito et al. 2015, (2)] worked on a classification of all existing articles and implementation of public interactive displays. All the examples enter in the classification.

Design challenges appear with the interaction going from showing that the user can interact with the display to convince that the interaction doesn't need many time or effort from him.

The type of data displayed depends of the distance between the user and the display. The system can't show personal data if the user can't hide the data using his body or just passing-by the display.

Displaying personal data forces to verify if the user in front of the display is allowed to see them. This means that authentication is important and necessary. Some authentication system were evaluated : Proximity based login, Microsoft Kinect identity, carpus and Mobile phone role authentication.

Needed properties were identified :

- Security : The private data are accessible through a secure system
- Privacy : The private data are displayed 'hidden' from other people (when leaving the screen or during concurrent usage)
- Attractiveness : People must see they can interact with the display
- Usability : People doesn't need to search how the display works
- Public access

None of the evaluated systems offer all those properties. All those authentication system are in controlled environment (inside an hospital, at home, at work) or propose open data only. The study proposes to cover all of those properties.

Before interacting and authenticating with a system, it must show information. This way a use case prototype was first developed to display data in the university of Namur following the design principles and characteristics. The methodology used to develop the prototype is the one from the UX Book [Hartson and Pyla 2012, (10)]. It consists of cycles with 4 steps : Analysis, Design, Implementation and Evaluations.

After some cycles, an electronic information board was presented and developed as a website using the javascript language. The information displayed are a map of the building, a list of current courses and a list of news. A visual link using colors shows the room where the course is done. All those data are refreshed automatically. Even if it is a local implementation it was developed with recommendations of the master in Computer sciences courses : modifiability, generalization and re-usability. This offers to implement it in another faculty of the University with a small effort.

A treatment of the menu of the restaurant available in a digital pdf format can be done a perspective to extend the current implementation.

At this stage no interaction is possible. Adding interaction raises the authentication issue.

The methodology used to address the authentication is the same as the one for the use case except that the study will not include the prototype. Some reflection cycles were also done.

The study covers and fills the following issues :

- Which data to display : The BVE form the university
- How the users access to his data : using a smart-device with encrypted token
- How the system keeps privacy of data : using an RGB camera to track user distance and acts when there is a change in interaction phases

The security of the hardware was not part of the study. It is a perspective that needs to be addressed in case of implementation. If the display offers masking personal data but a hacker can have a replication of the display on another device, the system is useless.

Add a tangible object in the secretariat and receive the status is also a good perspective. It will add interesting information updated in real-time.

Has human is unpredictable, a good perspective would be to record how the students are trying to interact with the display and make modification of the design according to the results or their needs.

Multi access with sharing of information can also be a good perspective for future works.

Bibliography

[1] Agamanolis, S. "Designing displays for Human Connectedness". In: *Public and Situated Displays. The Kluwer International series on Computer Supported Cooperative Work* 2 (2003).

[2] Ardito, C. et al. "Interaction with Large Displays: A Survey". In: *ACM Computing Surveys (CSUR)* 47 (Apr. 2015).

[3] Bardram, J., Kjær, R., and Pedersen, M. "Context-Aware User Authentication — Supporting Proximity-Based Login in Pervasive Computing". In: *Lecture Notes in Computer Science* 2864 (May 2003).

[4] Bird, J. and Rogers, Y. "The Pulse of Tidy Street: Measuring and Publicly Displaying Domestic Electricity Consumption". In: *Workshop on energy awareness and conservation through pervasive applications* (2011).

[5] Brignull, H. and Rogers, Y. "Enticing People to Interact with Large Public Displays in Public Spaces". In: *Human-computer Interaction, INTERACT '03* (2003), pp. 17–24.

[6] Brignull, H. and Rogers, Y. "Meme Tags and Community Mirrors: Moving from Conferences to Collaboration". In: *Proceedings of the 1998 ACM conference on Computer supported cooperative work* (1998), pp. 158–168.

[7] Brignull, H. and Rogers, Y. "Subtle ice-breaking: encouraging socializing and interaction around a large public display". In: *in Workshop on Public, Community. and Situated* (2002).

[8] Colville-Andersen, M. *Cykelbarometer – Bicyclists Count in Copenhagen.* 2009. URL: `http://www.copenhagenize.com/2009/05/bicyclists-count-in-copenhagen.html`.

[9] Dey, A. K. *Providing Architectural Support for Building Context-Aware Applications.* Nov. 2000.

[10] Hartson, R. and Pyla, P. S. *The UX Book: Process and Guidelines for Ensuring a Quality User Experience*. Feb. 2012.

[11] Haselsteiner, E. and Breitfuß, K. "Security in Near Field Communication (NFC)". In: *Workshop on RFID Security* (2006).

[12] Hernandez, D., Castrillon, M., and Lorenzo, J. "People counting with re-identification using depth cameras". In: *IET Digest 2011* (2011).

[13] Izadi, S. et al. "Dynamo: A public interactive surface supporting the cooperative sharing and exchange of media". In: *Proceedings of the 16th annual ACM symposium on User interface software and technology* (2003), pp. 159–168.

[14] Jong, J. de. *json Javascript editor*. 2017. URL: `https://github.com/josdejong/jsoneditor`.

[15] Li, J., Greenberg, S., and Sharlin, E. "A Two-Sided Collaborative Transparent Display Supporting Workspace Awareness". In: *International Journal of Human-Computer Studies* 101 (May 2017), pp. 23–44.

[16] Mankoff, J. et al. "Heuristic evaluation of ambient displays". In: *Proceedings of CHI* (2003).

[17] Morrison, A., Jacucci, G., and Peltonen, P. "CityWall: Limitations of a Multi-Touch Environment". In: *Proceedings of PPD* (May 2008).

[18] Muller, J. et al. "Display Blindness: The Effect of Expectations on Attention towards Digital Signage". In: *Tokuda H., Beigl M., Friday A., Brush A.J.B., Tobe Y. (eds) Pervasive Computing. Pervasive 2009* 5538 (2009).

[19] *Oxford English Dictionnary*. 2018.

[20] Peltonen, P. et al. ""It's Mine, Don't Touch!": Interactions at a Large Multi-Touch Display in a City Centre". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Apr. 2008), pp. 1285–1294.

[21] Pousman, Z. and Stasko, J. "A Taxonomy of Ambient Information Systems: Four Patterns of Design". In: *AVI '06* (May 2006).

[22] Ramakers, R. et al. "Carpus: A Non-Intrusive User Identification Technique for Interactive Surfaces". In: *UIST'12* (Oct. 2012).

[23] Research, M. *Kinect Identity: Player recognition in Xbox*. Microsoft. Aug. 2016. URL: `https://www.youtube.com/watch?v=q8kboXBqz_o`.

[24] Saggs, C. *Javascript iCal Parser*. 2012. URL: `https://github.com/thybag/JavaScript-Ical-Parser`.

[25] Sahibzada, H. et al. "Designing Interactive Advertisements for Public Displays". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (2017), pp. 1518–1529.

[26] Schöning, J., Rohs, M., and Krüger, A. "Using Mobile Phones to Spontaneously Authenticate and Interact with Multi-Touch Surfaces". In: *PPD'08* (2008).

[27] Skog, T., Ljungblad, S., and Holmquist, L. E. "Between Aesthetics and Utility: Designing Ambient Information Visualizations". In: *IEEE Symposium on Information Visualization 2003* (2003).

[28] Unamur. *ADE Web Dircet Planning*. 2018. URL: `https://www.unamur.be/direct/index.jsp?login=web&password=web`.

[29] VandeMoere, A. and Hill, D. "Designing for the Situated and Public Visualization of Urban Data". In: *Journal of Urban Technology* 19.2 (May 2012), pp. 25–46.

[30] VandeMoere, A., Tomitsch, M., et al. "Comparative Feedback in the Street: Exposing Residential Energy Consumption on House Facades". In: *Proceedings of the 13th IFIP TC 13 international conference on Human-computer interaction* Part 1 (2011), pp. 470–488.

[31] Vogel, D. and Balakrishnan, R. "Interactive Public Ambient Displays: Transitioning from Implicit to Explicit, Public to Personal, Interaction with Multiple Users". In: *Proceedings of the 17th annual ACM symposium on User interface software and technology* (2004), pp. 137–146.

[32] Wisneski, C. et al. "Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information". In: *Proceedings of the First International Workshop on Cooperative Buildings* (Feb. 1998).

[33] Xambó, A. et al. "Exploring Social Interaction with a Tangible Music Interface". In: *Interacting with Computers* 29 (Mar. 2017), pp. 248–270.