Emergent IoT configurations for same-place collaboration

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This thesis project describes a system to make presentations more collaborative, consisting on a mobile application using mesh technology.

The mesh network may be set up through the choreography of interaction created by attendees tapping their phones together at the start of the meeting. The fluid workflow for requesting and handing over control of the projector encourages sharing and makes the interaction between presenter and audience more collaborative.

The design was evaluated through a collaborative session that pointed at several future lines of work. Furthermore, we found opportunities to leverage the use of mesh networks in the workplace.

Finally, we carried out two explorations of the use of projectors and movement capture for the creation of visual content. This, along with the previous work, served as a base for the argument that there is an opportunity to discover rich interaction possibilities in the combination of small, modular IoT devices to create augmented spaces.

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Chapter 1

Introduction

For most people in a professional context, meetings and presentations have become a commonplace fact of life. Popular culture paints these gatherings as boring and dull monologues. Untold numbers of management books promise to make you a better presenter, capable of turning a repetitive presentation into a life-changing delivery.

As much as we tend to criticise meetings and presentations are, they are still very much in use. At the end of the day, we have to work together with other people, and PowerPoint communication is better (sometimes by a slim margin) than no communication at all. But there surely must be better ways to collaborate and create new ideas together.

At a time when many knowledge workers collaborate with remote disembodied colleagues on the crafting of digital materials, we still often rely on personal and tangible interactions when we need to work on complex problems. There isn't one single tool that solves all our needs: instead, people mix and match devices and physical media to accommodate their thought process and communication requirements.

When I was working as a professional developer, I would usually keep a notepad next to my laptop to jot down quick sketches as I worked on problems. Our office had blackboards on the walls, for people to meet around a physical space, chalk in hand, and discuss the arrangement of digital zeroes and ones.

While paper and other place-specific, tangible materials seem to be here to stay, new actors have entered the scenario. We bring our personal devices (phones, tablets, laptops…) to an space that is already populated by shared digital elements (projectors, screens, networks…).

This same-place collaboration brings about situations where several connected components combine into temporary sets of functions and services. The IOTAP project [1] at the University of Malmö refers to such collections as emergent configurations.

The emergent properties of these new ecosystems of devices and other de-

[1] http://iotap.mah.se/ecos/

sign materials are generally hard to overview, and they tend to change unpredictably. This opens the door to finding new connections and opportunities, carefully using interaction design to improve common situations.

The main research goal in this project is finding interaction design principles in order to support users in understanding, appropriating and effectively using those emergent configurations in the work place. We will make use of existing system architectures, information models and self-adaptive techniques as appropriate.

The main context of use will be one where professional collaboration takes place within a given physical space, mediated by personal devices as well as the shared elements (digital and non-digital) present in the space. Our starting point will be the interplay between shared stationary displays and projectors, and personal mobile devices, particularly smartphones.

In particular, we will focus on the following research questions:

- how could meetings and presentations become more collaborative?
- how could mesh networks improve collaboration in a work context?
- what other possibilities open up when we are able to connect devices such as smartphones and projectors with one another?

Chapter 2

Research method

The aim of this project is to carry out interaction design research on the field of same-place collaboration, focusing in particular on the interplay between components such as projectors and smartphones during presentations.

In the model of interaction design research proposed by Zimmerman et al. (2007), researchers tackle under-constrained problems by integrating existing behavioural models and theories, technical opportunities, and anthropological knowledge. This integration leads to an active process of ideating, iterating and critiquing potential solutions, during which researchers reframe the problem as they attempt to "make the right thing". The final output is a better understanding of the problem and the desired solution, along with the artifacts and documentation that ground those claims. Zimmerman's model focuses on artifacts as concrete embodiments of theory and technology, with the goal of producing knowledge and demonstrate significant inventions. These artifacts can then be used to communicate knowledge and inspiration to the design community of practice.

Löwgren (2007) explains how interaction design can lead to new, relevant, well-grounded and critizable scientific knowledge. This requires that researchers are able to move beyond the strict institutional norms inherited from computer science and HCI. Being a designer and researcher in an academic context demands appropriate design ability, in order to create artifacts of acceptable quality. Interaction design research would consist of a combination of: creating prototypes for empirical evaluation of new design ideas, examining the potentials of new materials and concepts, exploring possible futures, designing artifacts that instantiate more general theories, performing participatory design, establishing and validating semi-abstract knowledge, representing and communicating design artifacts, as well as assessing and critiquing their qualities in an interplay with creative practice.

Along similar lines, Obrenović (2011) described design-based research as a method that capitalises on the opportunities provided by the design of interactive systems to reach a better understanding of the problem, its possible solution, and the design process. This generates generalizable knowledge, providing a better insight into the problem domain, and the design guidelines and methodology. Design can reveal things that other methods can not, as it exploits the tacit and implicit knowledge of designers and users. The results of the research should be presented in a way that makes explicit the motivations and reasoning behind generalized claims, allowing for critical reflection and discussion.

With the previous in mind, the project begins with an introduction to the general problem domain of meetings, presentations and same-place collaboration, as well as a statement of the research questions.

This is followed by a literature review in which we look in detail at existing research work in the fields of workplace collaboration, use of projectors, and pen and touch interfaces.

After having laid out the problem domain in general terms and studied the state of the art, we then focus on a concrete problem. The starting scenario will be one where a presenter is able to wirelessly and smoothly use the stationary projector in a meeting room to display slides from their phone; audience members are able to temporarily take over the projector, for example to display a related image, after which the presenter carries on.

This design work allows us to look into the choreography of interaction between people and devices in workspaces, supporting their dynamic combination and reconfiguration in order to collaborate on complex problems. It also allows us to look in detail at the potentials and possibilities afforded by the dynamic creation of ad-hoc mesh networks, through a collaboration with Terranet AB within the context of the IOTAP research group.

The outcome of this stage is the creation of a high-fidelity behavioural prototype which demonstrates a relevant slice of the whole design: the presenter can select a document to display, move between slides, allow the audience to share their own images, etc. To support the use of a large display, a UI mode has been designed specifically for the case where a phone is connected to a projector and is mirroring its screen on it. The contents are fixed, while a real implementation would allow users to share their own images and documents. The prototype has been developed on Android, and makes use of Terranet's mesh network technology to exchange messages among several smartphones.

This artifact is used in a collaborative evaluation session to gather feedback, both about the concrete solution and people's general attitudes towards meetings and presentations in work contexts. This process of designing, building and evaluating a prototype provides us with valuable insights.

Those insights lead to an ideation phase where we explore future lines of work around three main lines. First, we describe the next iteration of the design by attending to the issues and limitations made apparent during the evaluation. Second, we look at opportunities for the use of mesh networks in collaborative contexts. Finally, we discuss two experiments that make use of projectors to create visual media, looking at the new possibilities that are opened by IoT technologies for the creation of augmented spaces.

To close the project, we summarise our results and address the research questions. Finally, we provide a critical discussion of the whole process.

Chapter 3

Theoretical framework

3.1 Introduction

The field of same-place collaboration is particularly rich in terms of concepts and ideas. Something to keep in mind as we look at augmented rooms and large installations is that most changes in the workplace in the last decades have usually been spearheaded by small, flexible devices that could first fit within existing practices, and over time come to create new ones.

From the PC to the smartphone, people have sought components that could be combined and repurposed with reasonable flexibility. Only in very specific circumstances is the construction of a full purpose-built room warranted: nevertheless, the fact that to collaborate on complex issues people tend to end up creating a full space inhabited by the data highlights three interesting ideas.

First, there is the fact that our cognition has evolved to make us adept at a large number of tasks. For instance, spatial memory and reasoning come easily to us, yet are not always exploited adequately by our tools. To tackle complex issues, it often makes sense to adapt the way information is represented and manipulated to make the most of the full capabilities of our brains.

Second, there are clear benefits in being able to easily share and reason about problems. Collaboration is much aided by having a medium that adapts to the way people are communicating and collaborating, rather than getting in the way and forcing people to adapt instead.

Third, in practical terms, a rich path for design research in this field is to take existing work on large installations, identify the concrete benefits provided by those (e.g. in terms of cognition, understanding, collaboration, and social interaction), and then design simpler components that could be combined to provide some of those same benefits.

This literature review focuses on two main areas. First, it looks into existing work around same place-collaboration, both looking at existing practices and at a range of design research developments in this area. Secondly, it reviews existing work on the use of projector, and on pen and touch interfaces.

3.2 Physical and digital workplaces

The adoption of digital technologies in the workspace has not been fully successful at improving our understanding and communication of complex issues. Critics of the cognitive style imposed by tools such as Microsoft's PowerPoint abound. One of the most eloquent is perhaps Edward Tufte, who in "Beautiful evidence" (Tufte, 2006) states that presentation software tends to be oriented towards helping presenters feel safe, rather than helping them craft valuable content that the audience can understand. The standard presentation shortens evidence and thought, and forces a single-path structure over every type of content. It encourages the presenter to break up data and narratives into small sequential units, rather than laying them out in meaningful spatial configurations or allowing productive engagement with the audience.

Many of the advantages of paper over digital media haven't changed substantially since O'hara and Sellen (1997) compared reading from paper to reading on-line, and which include support for annotation while reading, quick navigation, and flexibility of spatial layout. These in turn allow readers to achieve a deeper understanding of the text, gain a clearer notion of its structure, cross-refer to other documents, and interleave reading and writing. Whereas annotation on paper was smoothly integrated with reading, digital annotation at the time was cumbersome and detracted from the reading task. It also did not provide enough flexibility nor did it support the same expressiveness. Navigation through paper was quick and interwoven with reading, but became laborious on digital media, detracting from reading. Two handed movement through paper allowed people to interleave and overlap navigation with other activities. Subjects reading from paper used its tactile qualities to support navigation and to implicitly assess document length, and were able to leverage spatial memory to remember where things were. Laying out paper in space allowed the visualization of a great deal of information, and provided a holding space for quick reference to other documents.

As described by Sellen and Harper (2002) in the book "The myth of the paperless office", paper is still an integral medium to our work because it is well suited for certain tasks. This is still the case despite of its well-known limitations: it must be used locally, takes up physical space, does not easily support more than a few people working on it, is hard to revise and integrate into other documents, and is primarily a static visual medium. The book gives an ethnographically grounded outlook on how, rather than getting rid of paper, digital technology has shifted the point at which it is used.

On chapter 7, the authors focus on the future of paper. First, the coevolution of paper and work practices means that reductions in the use of the first would demand deep reorganisation of the second. Additionally, it is their opinion that digital alternatives still need to be better designed. Finally, they point out that the affordances of paper make it very suitable for some particular tasks: paper is a tangible physical object, a single sheet is light and flexible, and engagement is direct and immediate. It supports a large range of collaboration practices with particular spatial and embodied properties. The same characteristics that make paper less suitable for some tasks, at the same time support and afford others. For example, the tangible physical presence of paper can be seen as creating clutter and taking up space, but it also supports flexible navigation and allows it to be placed on workplaces in meaningful patterns.

Paper finds its natural space in the workplace around point-of-use activities and knowledge work. Its affordances help us come to grips with information: judging, solving problems, making sense, planning, or forming mental models. It also has a natural fit in social processes, particularly face-to-face, as an aid for discussion, reviewing, co-creation, and other forms of coordinated teamwork.

The coupling of multiple displays creates interactive ecosystems which call for new social and communicative considerations. This design space is explored in systematic detail by Terrenghi et al. (2009). The authors provide a taxonomy organised around the size of the ecosystem and the degree of individual engagement. The concept of coupling that they use helps focus the analysis by requiring that coupled displays share some of the input or output of a single user interaction, and that they have some link between their internal states (so it is not enough if this relation is implicit in the user's mind).

Wäljas et al. (2010) describe a framework for cross-platform user experience consisting of three main elements. First, the system requires an appropriate composition, with a clear structure of roles based on tasks and situations, and a modular distribution of functionality across components. Second, the system needs to support fluid task migration between devices, as well as synchronization of actions and content. Third, the consistency of the service should be emphasized across platforms and devices.

Many similar considerations were put into practice in the design of "Post-Hoc Worknotes" (Andersson et al., 2002), a concept design illustrating how workgroup collaboration could be supported by recording professional communication in an exhaustive fashion, processing it to extract relevant metadata, and finally providing powerful tools for subsequently processing and accessing the information.

3.3 Augmented meeting rooms

The Insight Lab (Lange et al., 1998) was an early inmersive environment designed to support teams who create design requirements documents through the interaction of computer-based technologies with objects in the environment. Team members could use paper and whiteboards to sketch, annotate, and display their work. For lack of better technological options at the time, bar-codes were used to link physical documents and digital multimedia data.

A more recent approach to augmented collaboration is the idea of "blended spaces" (Benyon and Mival, 2012): mixed reality environments in which the real and the virtual worlds have been carefully brought together, with access to content. The physical space can be described in terms of the people and objects that exist in it, and their topographical relationships. Likewise, the digital space can be described in terms of its information architecture, and the agents and people that populate it. Transiency and permanence are relevant considerations for both the physical and the digital.

This framework comes from work on setting up an augmented discussion room[1] with interactive tables, interactive whiteboard walls and several wall-mounted multi-touch screens (Haller et al., 2010). That set-up included a sketching application that supported seamless interaction with traditional paper: using a pressure-sensitive surface and pens that had both a stylus tip and a ballpoint (using Anoto technology), the users' notes and sketches onto the paper could be streamed in real-time to the system's computer. This automatically digitalised content could then be projected and interacted with on the whiteboards.

Moving away from the need for purpose-built spaces, Open Project[2] is a lightweight framework for remote sharing of mobile applications developed by Google (Negulescu and Li, 2013). This system allows a user to simulate the projection of a native mobile application onto a display (such as a PC monitor or a projector) using a phone camera. This communication is implemented via a small Android library on the phone which connects to a remote OpenProject server; the system controlling the projection can then get the images being shared by accessing that server through a Web browser. The set-up process requires pointing the phone camera at the desired surface, where a QR code is used to pair smartphone and projector.

The use of projectors can be combined with depth cameras in the room. Wilson and Benko (2010) describe a room installation instrumented with multiple depth cameras and projectors. Graphics can be projected onto any surface, which allows for the emulation of interactive displays on uninstrumented surfaces, as well as facilitates mid-air interactions between and around these displays.

A similar set up also using depth cameras is discussed by Bragdon et al. (2011), where gestures to interact with the content being projected are available for the audience taking part on a code review.

[1]Video available at `https://www.youtube.com/watch?v=cPq5zzkI0GQ`

[2]Video available at `https://www.youtube.com/watch?v=w286qmNVBFctext`

3.4 Personal projectors

Cao and Balakrishnan (2006) explore the design space of dynamic interaction with digital content by means of a hand-held projector and a pen. The projector allows information to be displayed on any surface and naturally supports its use as a "virtual flashlight", revealing different parts of the digital world depending on distance and orientation. The pen is used for user input, such as annotation and selection of commands. The authors envision this technique as a way to leverage spatial information to explore complex domains by allowing the user to physically "place" the data on the world around. However, one clear limitation is that it does not afford peripheral awareness: only the information directly in front of the projector will be displayed. In a way, it is like exploring a dark studio with only a flashlight in your hand. This suggests that, even if a projector can be easily moved from place to place, it might be better for it to remain static when in use.

Another instance of combining pen and projector is provided by Kim et al. (2013), where the projection is used as an aid for physical drawings. Like in other cases, this system allows artists to control the projected images through gestures with their non-preferred hand. The main goal of this work is to provide more venues for creativity, for example by allowing artists to use projected pictures as reference or by exploring the consequences of drawing and colouring choices before committing them to paper. The authors envision a pico-projector being embedded directly into the pen, which might mean that the image would be moving continuously: for the time being, it seems more reasonable to use a separate projector on or under the drawing table, as they have done for their prototypes.

Another approach to the use of personal projectors is to display the images on non-planar surfaces, distorting them to fit the perspective of the viewer. One example is OmniTouch (Harrison et al., 2011), a wearable prototype that combines a personal projector with a depth camera to enable graphical, interactive, multitouch interactions on everyday surfaces. The prototype used by the researchers is composed of a depth camera, a pico-projector, and a metal frame that participants wear on their shoulder. The depth camera is the main input method: it detects the position of projection surfaces (so the projection can be adjusted accordingly) and hands (so clicks and other interactions can be identified).

3.5 Pen and Touch

A promising application of personal projectors paired with depth cameras could be their use as aids for sketching on paper. This would lead to the creation of mixed media content, composed of physical marks as well as digital projections.

In the coming chapters, we will talk about exploring the creation of this kind of content as an aid for ideation, understanding, and communication.

One challenge with pen-based interfaces is how to switch between modes for entry of uninterpreted ink and of gestures that may be translated into commands for the system. The lack of a suitable mode-changing technique makes pen-based interactions lower and more cumbersome. Li et al. (2005) carried out an experimental analysis of five different mode switching techniques. Their results suggest that using the non-preferred hand to signal this mode-switching offered the fastest performance when compared with techniques that overloaded the pen itself (via a button or an eraser end) or the gesture of writing (via press and hold or changing pressure).

A similar idea was put into practice in the design of "Manual Deskterity" by Hinckley et al. (2010a), a scrapbooking application inspired by with the way designers work with boards and notebooks. The authors defend a clear division of labour between pen and touch: the pen writes, touch manipulates, and the combination of pen and touch provides new tools. Touch interaction by the non-preferred hand is used to navigate the canvas and to create and manipulate objects. Only the pen produces ink strokes (although in some contexts the finger can be used to smear colours). This division of labour does away with the need for explicit mode switches, and even supports graceful degradation to one-handed usage. The authors then explore the rich design space created by combining pen and touch to implement tools such as grouping objects, cutting them, using them as temporary guides or rulers, copying and duplicating them, etc.

The space of pen and touch is a rich one, which offers the opportunity to craft new user experiences that leverage many of the advantages in how people naturally work with pen and paper. Further considerations on the same project are detailed by Hinckley et al. (2010b). As mentioned, they assign unimodal roles to pen and touch separately: one writes, the other manipulates. One-hand usage is efficiently supported, as the user can simply tuck the pen and use the fingers of the preferred hand. Multimodal interaction with pen and touch supports new tools: touching and holding an object makes pen strokes be recognized as gestural commands instead of ink. This technique for switching between different modes by performing a continuous physical action is defined by Raskin as a "pseudo-mode".

The same authors extended the above work by exploring different sensing techniques for tablet and stylus interaction (Hinckley et al., 2014). In this research, they explored how an awareness of grip and motion could be used to leverage how users naturally manipulate tablet and stylus devices. For example, they can detect how the user is holding the pen, which hand is being used for touch input, or how the tablet is being gripped. These signals may be combined to tailor interaction to the context.

A case where rich expressiveness is added to a digital stylus is Conté (Vogel and Casiez, 2011), a small input device inspired by the way artists use a crayon for drawing. The Conté is shaped like an elongated rectangular prism. The input system is able to detect which corner, edge, end, or side is contacting the display, thus affording the possibility of having different interaction modes associated with each one. For example, ink drawing could be performed by using one corner of the device, while laying it flat on one of its sides would make it function as a ruler.

Chapter 4

Designing a concept for more collaborative presentations

4.1 Context

Meetings and presentations tend to become monologues. This is partially because of the social and organisational contexts in which they usually take place, but also because of limitations in the current technology. The reliance on slides that are displayed by a projector one set at a time reinforces a certain static style that is hierarchical and not too encouraging to audience participation.

Presentations in particular often need to be preceded by a lengthy set-up process, where the presenter has to take out their laptop and plug it to a static projector. Everybody in the audience needs to be facing the surface where the presentation is being projected, and they can not easily show their own content. Handing over control of the projector is a cumbersome process that leads to only having one person presenting at any one time. This turns meetings into an almost theatrical performance, where the roles of presenter and audience tend to be separate and fixed.

Our goal is to turn these presentations into more collaborative sessions. One of the reasons why they tend to become monologues are the limitations of technology: getting access to the projector is a big barrier. The system sketched here would lower that threshold, encourage sharing, and ideally change the tone of a presentation into something more collaborative.

The goal of the design described and evaluated in this chapter is to introduce a way to share and display information in meetings that makes them more collaborative. The gesture of tapping phones to start the meeting is a nice social choreography that helps put attendees in a productive mood. People can volunteer content and the presentation is not predetermined, but rather becomes a shared event where a team collaborates to reach a common understanding of a problem.

This first line of work also served as an exploration on the use of mesh networks for same-place collaboration, encouraging sharing among presenter and audience, and introducing new gestures to get the meeting started. A final product would be well within the limits of existing technology, as shown by the working behavioural prototype and the fact that the mesh network has enough bandwidth to handle the load.

This leads us to the design openings:

- how can mesh networks be leveraged in a work context?
- how can we reduce the time it takes to set up a presentation, without needing to fiddle with cables or even connect to a permanent wifi network?
- how can we let people carry out a meeting with only their smartphones?
- how can we allow the audience to interject their own content during a presentation?

Our starting point will be an scenario where a speaker gets to a meeting room carrying only their phone, starts a presentation, and is able to hand over control of the projector to audience members so they can display related content.

4.2 Design

4.2.1 Creating the network

Figure 4.1: The presenter as intermediary between the shared projector and the mesh network.

This project uses mesh network technology from TerraNet AB [1]. A mesh network is a type of topology in which each node relays data for the others. In

[1] `http://terranet.se`

other words, it is a network with a flat structure, where all nodes cooperate in the distribution of data. Terranet's offering is based on the IEEE 802.11 mesh mode protocol [2], plus a range of proprietary optimizations to expand reach and reliability.

This technology was initially aimed at deploying local mobile communication to isolated rural areas. Its properties make it particularly relevant for cases when there is no infrastructure, when the infrastructure is not functioning for some reason, or when the existing network is suffering from congestion. One of the goals of this project was to explore ways in which these kinds of ad-hoc local networks could also be of benefit in the workplace.

Mesh networks use the same channels of the electromagnetic space as regular wireless networks, and each one is identified by its channel and "mesh ID" (analogue to SSID in wifi). Mesh-enabled devices can be configured to always join the same network (if there aren't other devices in range, this means creating the network anew), or they can operate in scan mode, identifying the available networks in the area.

In our case, this translates into three different ways for the attendees to join the mesh network for the meeting. First, their devices could have been configured beforehand to always join the same network, so e.g. members of the same institution or team remain connect automatically when they are together. Second, the devices could perform a scan and identify the existing mesh networks in the area, letting the user choose which one to join.

The third possibility, the most interesting from an interaction design point of view, is to join the mesh network through NFC by tapping the presenter's phone, or the phones of other members of the audience that are already part of it. The tapping gesture is personal and physical, it helps put people in the mood of working as a group better than if everybody had to be looking at their phones. It might become a sort of handshake that gets the session started. This small choreography of interaction helps turning a meeting into a collaborative experience.

4.2.2 Interaction

Once the network has been created, the presentation can start. The presenter selects the document to be displayed, and its first slide is shared with the audience. As the presenter moves from one slide to the next, the contents that the audience see are updated as well.

At any point, an attendee can select one of her own images and request to share it with everybody else. This needs the permission of the presenter, who is asked to cede control of the projector. Once the presenter agrees, everybody in the audience receives the image shared by the new speaker, who can then

[2] `https://standards.ieee.org/findstds/standard/802.11s-2011.html`

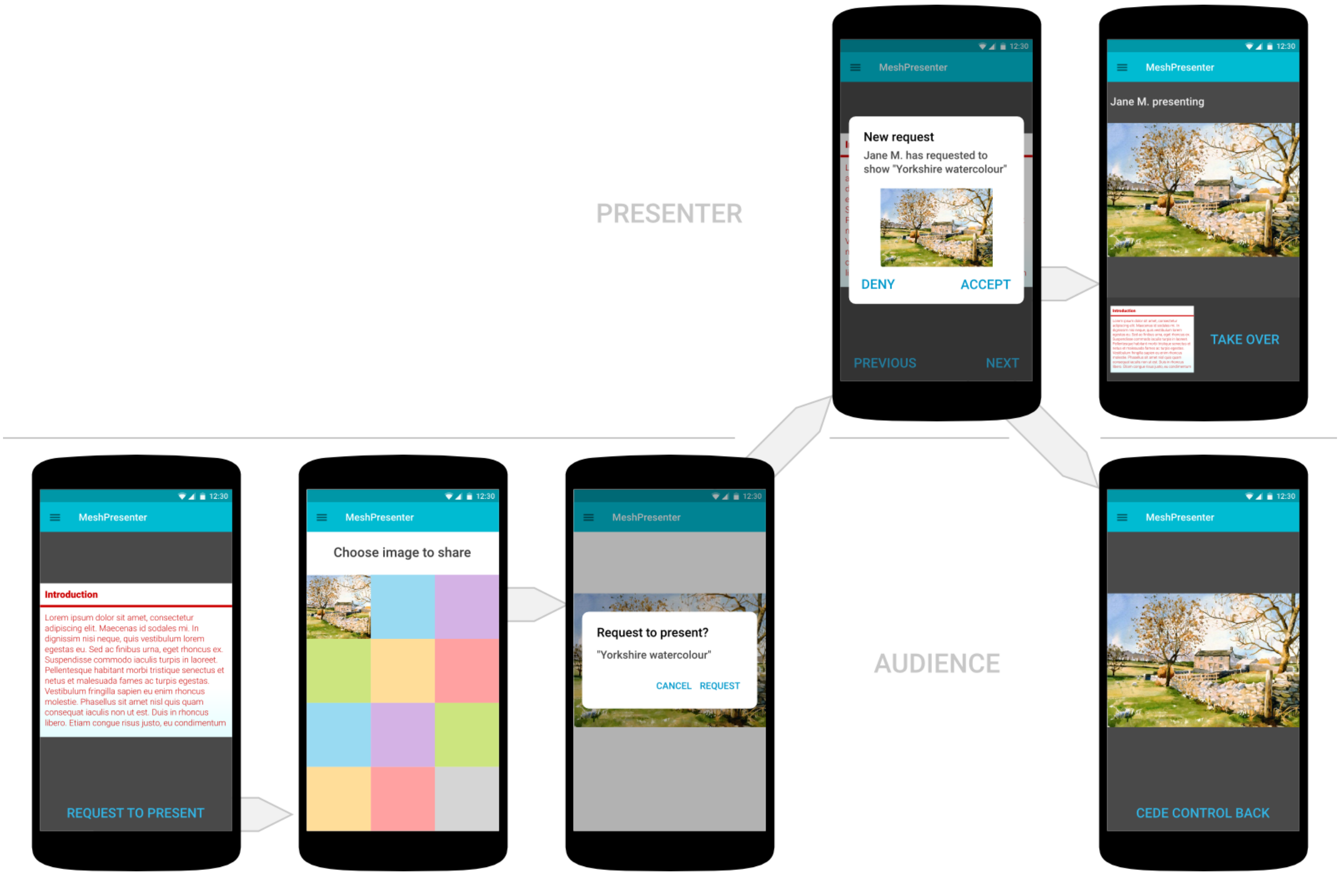


Figure 4.2: An audience member requests to present a relevant image. The new speaker can cede control back, or the presenter can take over to continue the presentation.

proceed to explain it in the context of the ongoing presentation. For example, the presenter might have been using maps to describe a certain area, and a colleague would like to show and explain a photograph taken at that location.

There are two ways to resume the original presentation. On the one hand, the new speaker can choose to cede control back to the presenter. On the other, the presenter can use the application to take that control back. Figure 4.2 illustrates this.

This interaction, starting with the creation of a situated network and continuing with the fluid sharing of the projector, opens the door to more collaborative types of meetings. The audience may ask questions and illustrate them with their own content. The presenter could take on the role of a moderator, passing control to each of the audience members in turn.

4.2.3 Displaying content

There are several possibilities for displaying the content. The simplest set-up is one where there isn't a projector and each person in the audience is looking at their own device. For obvious reasons, a meeting where each attendee is fixated on the screen in their hands could lead to lower engagement in the ongoing discussion.

Some modern phones are able to use an adaptor to connect to a projector and mirror their screen there, so another possibility would be to have a phone solely dedicated to displaying the content. This is what has been done in the prototype through the implementation of an special "projector" mode.

We could think then of a future "smart" projector which would be able to become a node in the mesh network by itself. The presenter would start the meeting by tapping this projector with their phone, joining the mesh network, and would then be able to push content to it.

4.2.4 Summary of the concept

To recap, this concept provides a way to wirelessly carry out a presentation using smartphones. The presenter can change slides and these changes are immediately propagated to the audience's devices. Attendees can request to share content with the presenter's permission, without causing any major disruption on the flow of the meeting. Communications among devices are carried through an ad-hoc network using mesh technology.

At a high level, the concept is not very unique: there are existing technologies to connect phone and projector, e.g. Negulescu and Li (2013). The main contribution is in details that make for a more elegant and thoughtful design.

The first is the possibility of tapping to get a meeting started, creating a social choreography that brings a group together.

The second is how the application creates the possibility of interplay between presenter and audience, introducing an meaningful parenthesis in the ongoing presentation through the graceful hand-off of the projector.

These details are quite significant for the value of the design, and are very relevant in the context of the project: they aim to make the presentation more collaborative, and they stem directly from the values outlined at the start.

4.3 Prototype

A behavioural prototype was developed, consisting on an Android application that ran on phones that had been set up with the Terranet mesh network technology.

The application supports three distinct roles. First, the presenter is able to select the initial document to be presented and control who is able to access the projector. Second, the audience may request access to the projector to display their images. Third, a special role is provided for the projector itself, which simply shows the current slide without any other interface elements; the reason for this last role is that it makes it possible to connect a phone to the projector and mirror its screen there, thus allowing presenter and audience to carry out the meeting wirelessly. Figure 4.3 shows three phones assuming each of these roles. In the future, it is not hard to imagine "smarter" projectors that would be able to join the network by themselves.

The prototype was a partial implementation of the complete design for the purpose of getting insights and inspiration. It largely covered the intended behaviour of the complete solution, but required that the slides were distributed to all participants beforehand as part of the Android application. This made it possible to use a simple JSON-based communication protocol, where small messages were exchanged over UDP to indicate each event of the interaction. This was simpler to implement than having to deal with file transfers, which are nevertheless supported by the underlying network technology. This limitation still allowed great flexibility in terms of content, so a realistic scenario could be enacted.

While it used a mesh network, the prototype did not support its creation through NFC tapping. For the tests, the network was set up beforehand, and the tapping choreography was role-played.

Upon launch, the application asks for the name and role (presenter, audience, projector) of the user. This step would not be necessary in a real application: the username would be obtained from the operating system, and the role would be implicit.

The prototype application has been tested on several Android phones running CyanogenMod with a custom network stack that includes mesh network technology provided by Terranet AB. The process for creating a mesh network between two or mode devices supports NFC: a new phone can join the network by tapping another one which is already connected. This opens the door to setting up physically located ad-hoc networks with a simple physical gesture. Communication between nodes is encrypted, which is of special relevance in a professional context. This might allow for increased security than using remote corporate servers or cloud services, and also for carrying out collaboration outside of the work environment, even if a connection to the broader Internet is not available.

The bandwidth provided by this technology supports sharing messages, images and phone calls. When there is only one hop between sender and receiver, it is possible to stream video. In the context of the current work, this means that the network capacity would not be an obstacle for the implementation of the solution outlined here.

A detailed walkthrough of the prototype can be seen in pages 24 and 25.

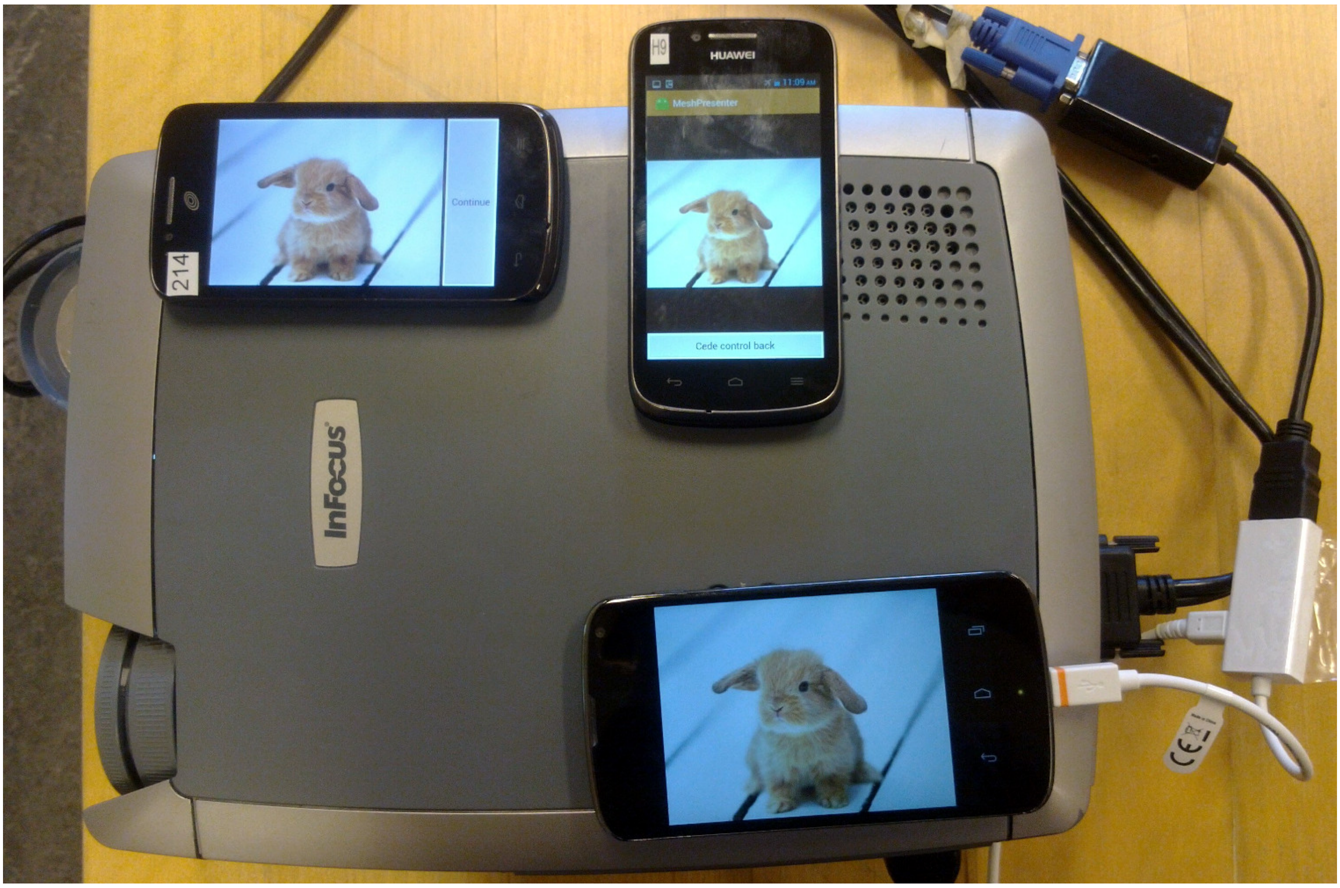
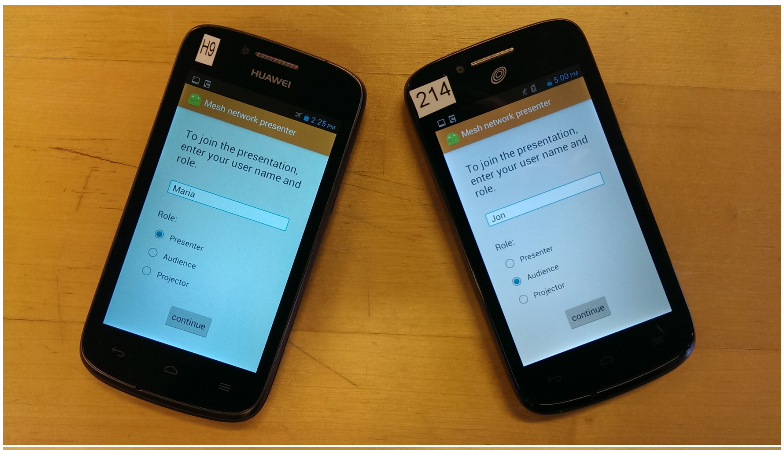
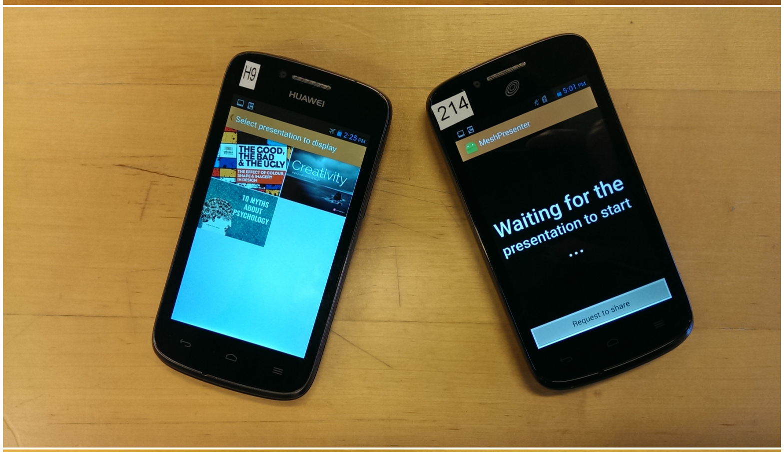


Figure 4.3: Three smartphones connected to the mesh network, sharing an image. The one at the bottom is mirroring its screen on the projector. The two on top would be in the hands of presenter and audience.

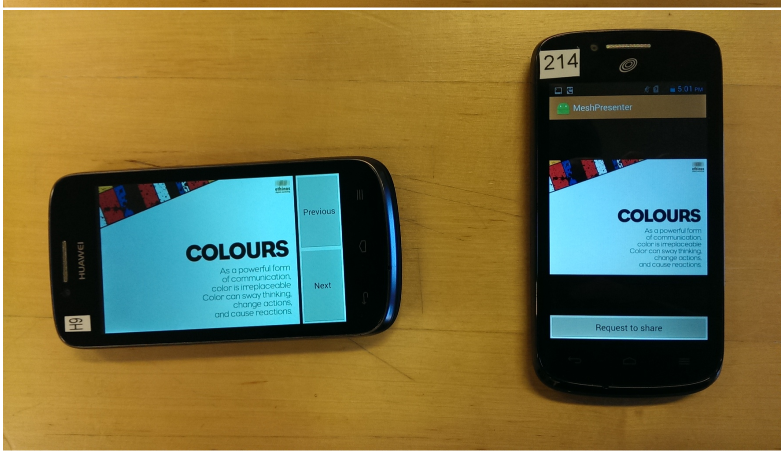


The first screen in the prototype lets the user select the role that they will play in the meeting: presenter, audience, or projector (a special mode to be used when the phone is mirroring the contents of its screen to a projector).

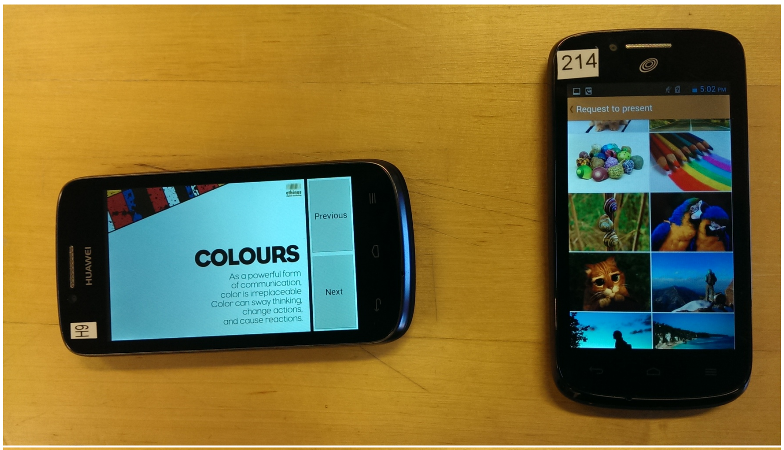


The presenter selects the document to be displayed, while the audience gets a placeholder.

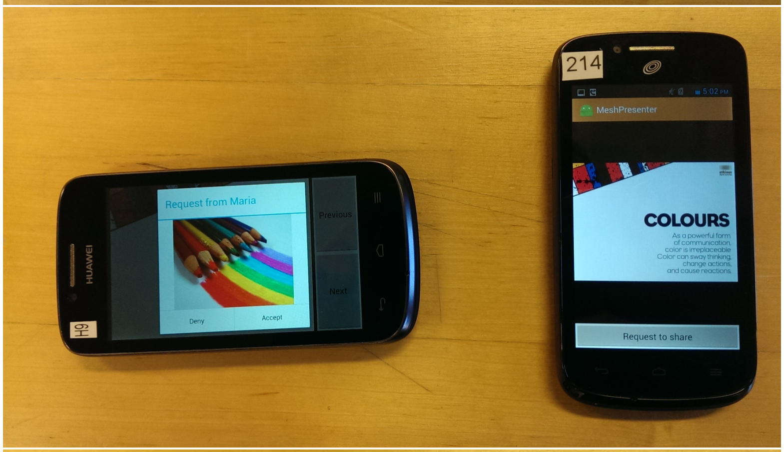
The presentation has started.



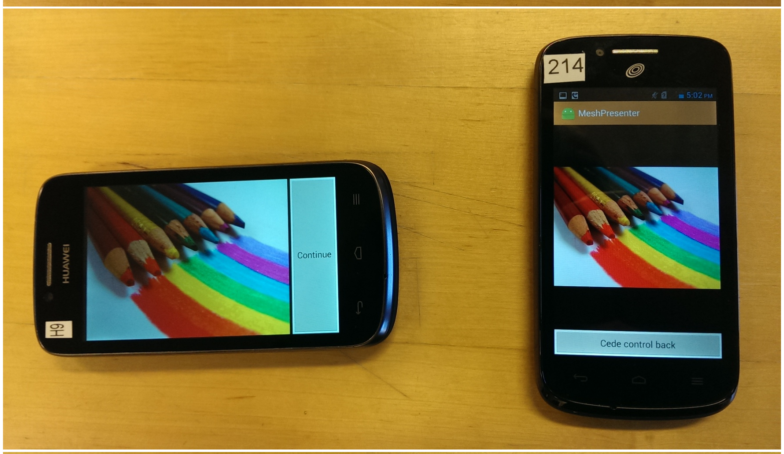
As the presenter moves through the slide deck, the current content is shared with the audience.



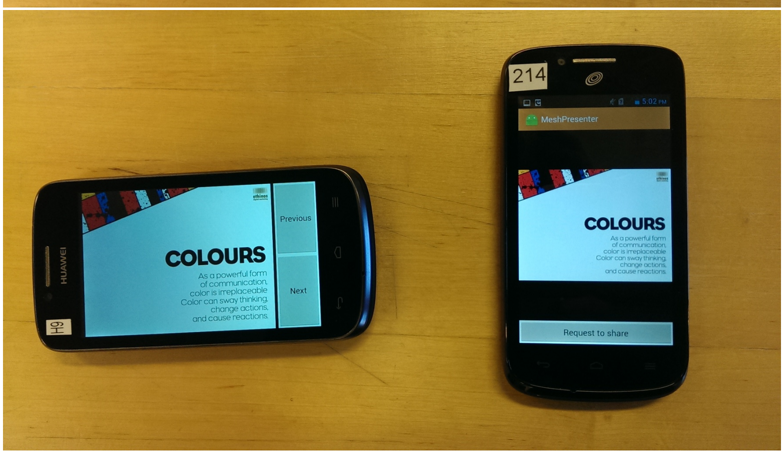
The audience member can tap on “Request to share” to get a list of images.



Selecting one of those images sends a request to the presenter that the audience member wants to take over.



Once the presenter accepts the request, all participants get the image that has been shared by the audience member.



To go back to the original presentation, the presenter can tap “Continue”, or the audience member can tap “Cede control back”.

4.4 Evaluation and results

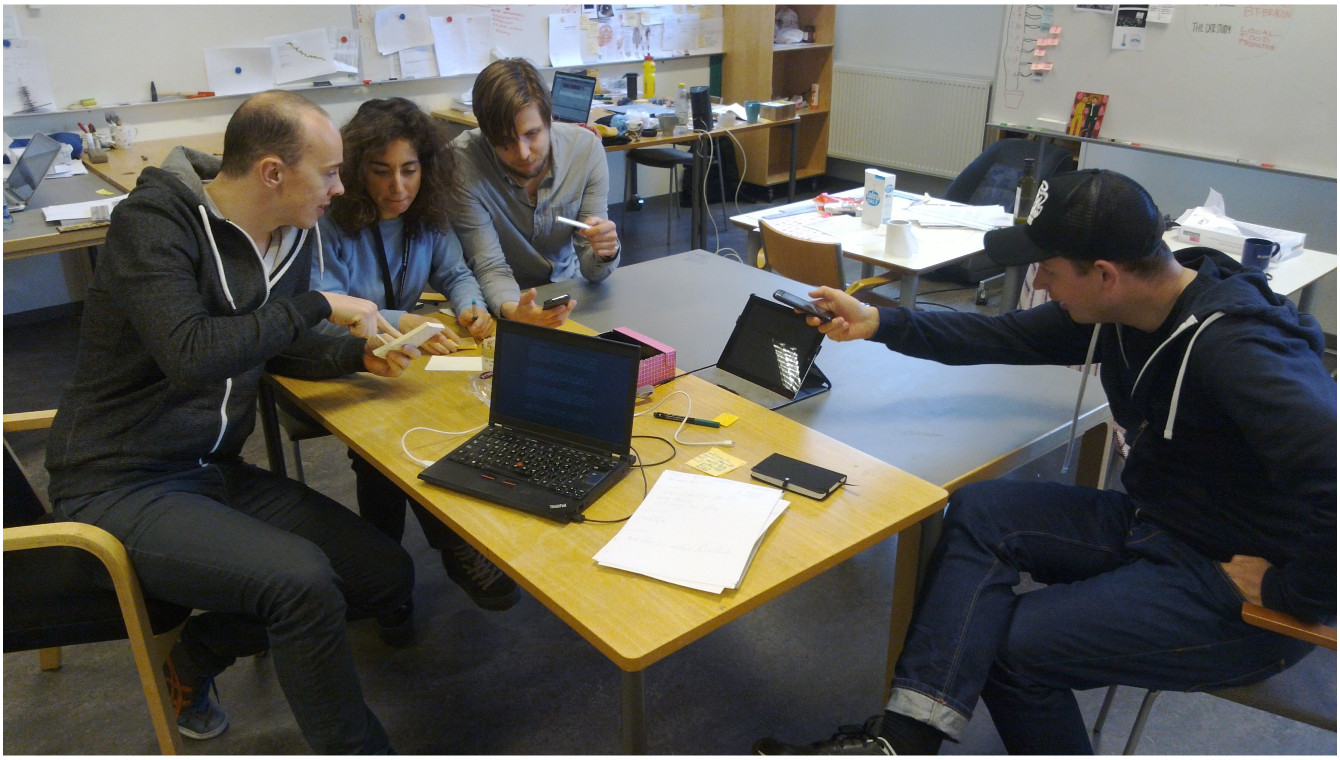


Figure 4.4: Participants in the collaborative session

4.4.1 Set-up

A collaborative session was organized to evaluate the design, using the prototype as a probe to elicit more knowledge on the general culture around meetings and presentations. The participants were four design master students between 25 and 30 years old, with experience giving and attending presentations in academical and professional contexts. The goal of the session was not so much user testing and validation, but the generation of new concepts and insights.

4.4.2 Collaborative session

The session started by asking the participants about their own experiences with good and bad presentations. They asked me to specify the concrete context in which those had taken place (workplace, meeting with a customer, classroom. . .), but I chose to leave that question open.

They described bad presentations that they had attended and the mistakes that had made them so, like putting too many words on the screen, reading from paper and not using visual elements. The charactertics of the location were seen as very relevant, and participants mentioned issues of room size, noise, light and general atmosphere.

Good storytellers were very appreciated, as they don't need complex slides (or even any slides at all) to deliver an engaging and informative presentation. This raised the question of whether a presentation had to necessarily entail using Powerpoint or similar tools, instead of e.g. following a script or giving the audience a brief to read beforehand [3].

Some examples that came up in the conversation:

- Nancy Duarte: Slideology, Resonate.
- Applications: speakerdeck, slideshare, Prezi, keynote for iOS, Apple TV.
- Elon Musk talking about batteries. Steve Jobs.
- Collaborative use of Prezi in the classroom: students can go back and forth through the slides
- Official TED talks: more entertainment than information
- Math/physics presentations with storytelling and physical props
- Dutch teachers deliver lessons through YouTube: University of the Netherlands asked students about their best teachers, and then had those teachers record 10 minute lessons and put the presentations online
- Khan academy
- Medical explanations for the elderly about how to use medical devices

We spoke about how presentations are used in a professional context. For one participant, a product designer, work meetings tended to be relaxed and focused on the concrete physical work, with few people in attendance and no presentations. Other participants had worse experiences, and one complained that "if you can't tell a good story, send an email instead". There is a popular image of work meetings that paints them as boring and hard to follow. Depending on personal relations, sometimes speaking in meetings can feel artificial or forced.

Presentations tend to become monologues; one reason for this might be technological limitations, for example in access to the projector. The main aim of the design is to have presentations that are not strictly predetermined so, by encouraging audience participation, the social dynamics can move from hierarchical to more collaborative.

I described to the participants the underlying mesh network and how it could be set up on the spot. Then, I demonstrated the behavioural prototype,

[3] Apparently, Amazon uses the latter strategy.

clarifying which functionality it covers. The general question to the participants was how a solution like this could help with some of the issues previously described, and which other concerns it raises.

Since holding a meeting at a welcoming space was an important consideration, the ability to take the meeting somewhere else was seen as highly relevant. Using a mesh network would allow colleagues to move without caring about existing connectivity, as they would be able to set up a secure ad-hoc network everywhere.

The design was considered appropriate for meetings among a small number of work colleagues, but there were doubts about how it would fit other contexts and audience sizes. For a bigger audience, it might be necessary to display smaller notifications and allow the presenter to temporarily disable requests.

Having a pointer was seen as an useful feature (Keynote for iOS already does this). Related to this, a participant mentioned that the ability to signal things in other people's screens might be employed to demonstrate how to use a smartphone.

A nearby venue for informal talks, FooCafe, hands out cards in different colours to the audience. During the talk, the audience can hold up the corresponding card to signal that they would like to ask a question, provide additional information, or deliver an urgent notice. Along similar lines, participants in the workshop perceived the need for the audience to be able to request the turn to speak without needing to show an image.

A relevant consideration is that the summary of a meeting using this solution would not just be the original presentation, but would also have to include the images that the audience shared. Participants also mentioned the need to annotate slides and to go back through the content that has been presented.

To finish the workshop, we moved the discussion back to the broader context of meeting and collaboration. The intention was to see if the previous talk about different design possibilities would bring about new concepts and ideas.

It was clear that the current design is better suited for one particular type of meeting. This is a valuable insight, as those perceived limitations can be turned into potential new lines of work.

Participants asked if the design is trying to improve the presenter's experience, or the audience's. The answer is that it tries to blur the lines between the two roles, ideally providing improvements for both. One of the goals that I kept in mind while working in the design was to let people have a meeting by bringing just their phones, to let them choose the most convenient space and focus on collaborative discussion. Ideally, the presenter would take more of a moderator role among colleagues.

I wanted to leave technology in the background in order to prevent an usual sight in business meetings: a room of people hiding behind their laptops, not looking at each other. Yet the participants raised the concern that this concrete design makes it acceptable for people to be looking at their phones during a meeting, which might encourage distraction.

This solution is a better fit for a flat social structure, and there is the question of how it would match a more hierarchical set-up (such as a conference or lecture). One venue for research would be to modify the prototype by relaxing or strengthening the role of the presenter, either by letting the audience change slides without permission, or by letting the presenter temporarily disable such requests altogether.

In terms of the communication of the design, there was a complaint from the participants about the lack of enough storytelling when demoing the prototype. This needs the creation of appropriate content (not just new slides, but also images that might be shared along with those), and is a work in progress; it might be that the content in the demo would need to be tailored for each audience. Additionally, it was hard to visualize the complete design without a working connection to a projector.

4.4.3 Outcomes

Overall, the session was very productive. Perceived limitations of the current design could now be followed on as new potential lines of work. Preparing the session forced me to work on clarifying how the context and design are communicated. There was still work to do on the demo side, specially in terms of content, storytelling and on connecting the phone to a projector.

An important insight was the relevance of the location where a meeting takes place, which can be a good argument for using mesh networks in a work context.

It was clear that the design was better suited for a particular type of presentations: work meetings with a small audience and a rather flat social hierarchy. Therefore, one way to evolve the design would be to explore how to make it more appropriate for large audiences and/or more hierarchical roles (e.g. at a conference or lecture), for instance by temporarily disabling requests or by adding new kinds of notifications (e.g. to request the turn to speak).

Another request that came out of the session is the need for a digital pointer, so the presenter and audience can direct the attention to particular details of the image being projected.

The above features are aimed at improving the case where presenter and audience are sharing the same space. Even though this might get out of our original scope, it might be worth exploring how to make the design more suitable when presenter and audience members are attending remotely.

Chapter 5

Future lines of work

It is now a good point to look back at the three research questions posed as the beginning, to see how the work in the previous chapters has moved us towards answering them. As it tends to happen in design, what we found as we explored the problem domain and possible solutions were not definite answers, but more concrete and focused questions that reflect an increased understanding.

Regarding the search for ways to make meetings and presentations more collaborative, the previous design and prototype show a promising path: allow fluid sharing of the projector in the room through each attendee's smartphone.

The prototype focuses on slide decks and images, but we could think of how it might be expanded to allow sharing other content using the mobile OS's design language. The only action that the audience carries out through the application is requesting to share an image, but in large spaces there would be the need for more types of audience notification. The context of use for the prototype only contemplates one presenter, hence raising the question of how we could coordinate multiple ones. Another relevant feature that came out in the evaluation was pointing at details in the current slide. An interesting consequence of this fluid, unscripted collaboration is how the presentation could be stored after it has been enriched by the audience's contributions.

The design and prototype demonstrate a use case for mesh networks in a work context. The evaluation emphasized the importance of the location where a meeting takes place, and hence a mesh network could be a way for a team to move to a more convenient space while remaining securely connected. For large spaces, supporting voice transmition via the mesh network would be useful to avoid requiring a complex configuration of speakers and portable microphones. Since mesh networks are restricted to a single location, the possible integration of remote attendees appears as an open question.

Finally, I have done some conceptual work looking for possibilities that appear when we are able to connect devices such as smartphones and projectors with one another. These ideas are not implemented or validated, but they suggest new directions for research on the use of IoT for augmented spaces.

We could think of smarter projectors that can join the located network and present contents independently. Projected images could be used to aid sketching and reflection. The combination of a projector with a personal computing device could allow for the spatial arrangement of documents and notes, leveraging peripheral awareness through the ad-hoc creation of smart rooms.

5.1 More collaborative meetings

5.1.1 Sharing

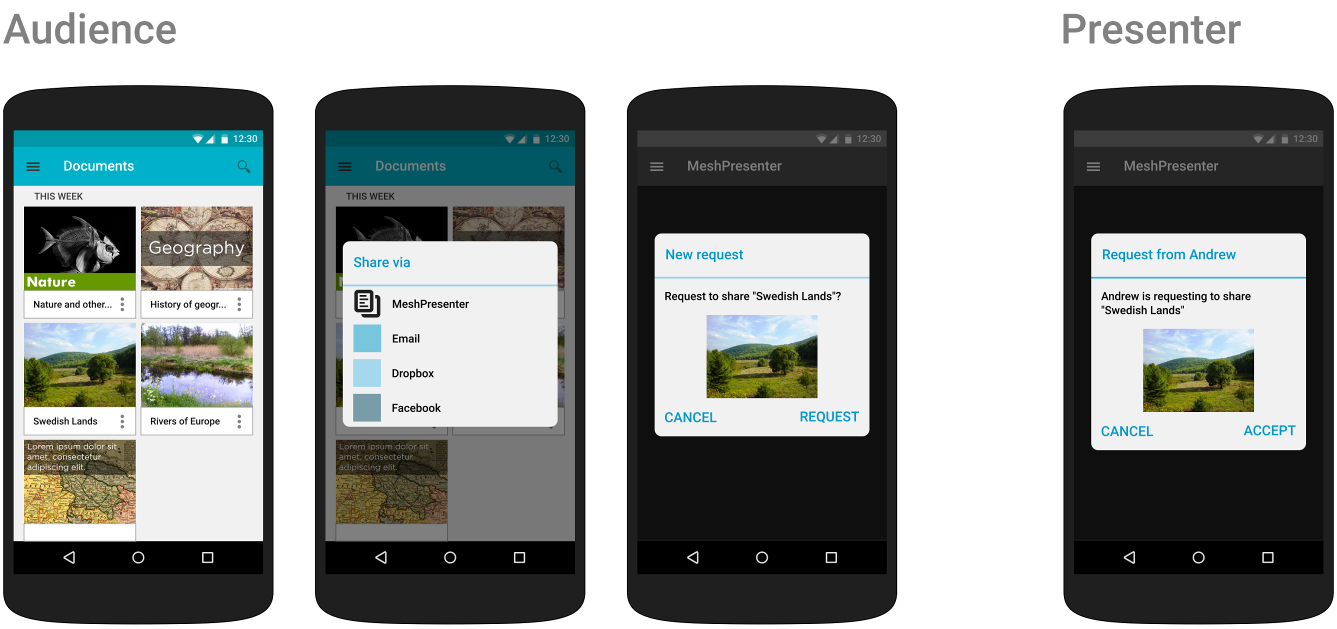


Figure 5.1: Use of the "Sharing" feature from another app. A person in the audience selects a document on their phone and chooses to share it via our app. This opens the app, and the user confirms the request to present. When this request is sent, the presenter gets a notification.

In the current design, the documents to be shared are already contained in our application. However, we could exploit the functionality provided by mobile operating systems for inter-application communication, so those documents could come from other sources.

Figure 5.1 shows a possible implementation using the Sharing functionality in Android to allow people to share content from other applications.

5.1.2 Accommodating different audience sizes

The social hierarchy implicit in the application can be enforced or minimised to accommodate different contexts of use. The current design, where only the presenter can change slides and attendees need permission to share, works best for medium-sized audiences.

It might be necessary to add new types of requests besides getting access to the projector, such as making a question, providing additional information, or delivering an urgent notice to the audience.

With a large audience, we could make it so the presenter is able to temporarily disable audience requests, or even silence particularly disrupting attendees. For smaller and more collaborative meetings, these constrains could be lifted so the audience doesn't need permission to draw or push images to the projector; the display surface would then become a shared medium in a flat social hierarchy.

This shows how we can take our design and prototype as starting point to accommodate a range of social configurations between one presenter talking in front of a mostly passive audience, and a flexible meeting where participants share images as needed.

5.1.3 Handing control over

The starting point for the design was the common situation of having one presenter and several attendees. Which leads to the question of what happens when we have more than one presenter in a meeting.

The problem of managing several presenters can be made simpler if it is acceptable to have only one at a given time. In this case, being the current presenter could be implemented as a token that people receive and hand over. This approach is similar to existing meeting techniques[1,2] where a prop is shared between attendees to signal who is speaking at each time.

Nevertheless, this adds an additional complication to the design and needs careful consideration to create an appropriate mental model. We would also need to contemplate its interaction with the underlying technology, such as what happens if the current presenter leaves the network.

5.1.4 Pointing

One of the features that was requested during the collaborative evaluation was to allow the presenter to draw on the projected image, in order to bring attention to particular features. Figure 5.2 shows an example where the presenter annotates a map. Existing solutions, like Keynote for iOS, already have this functionality.

[1] https://en.wikipedia.org/wiki/Talking_stick
[2] https://en.wikipedia.org/wiki/Council_circle

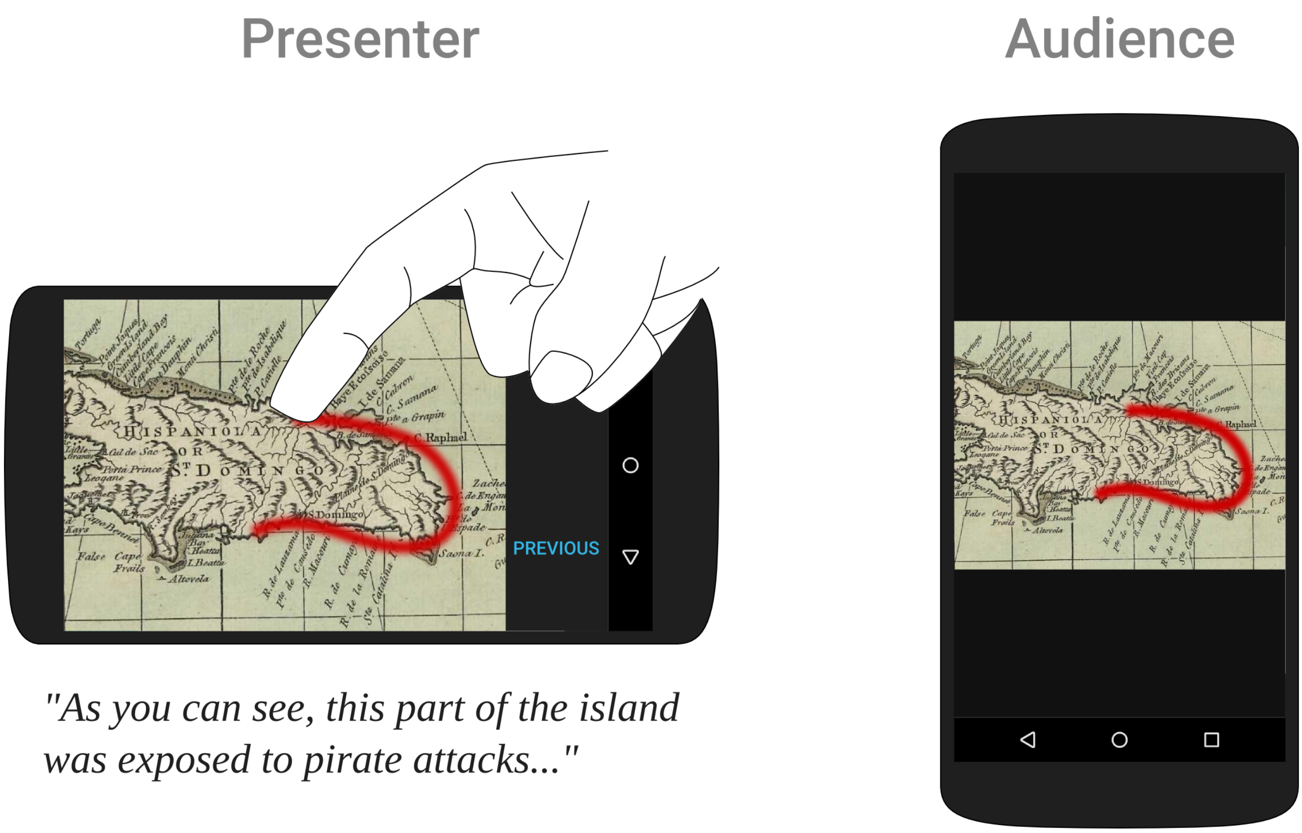


Figure 5.2: The presenter can draw on the image to bring attention to relevant features.

5.1.5 Summarizing meetings

The summary of a meeting carried out using this solution would be composed of the original presentation, plus the images and content that the audience shared. This could be automatically assembled and made available to attendees after the meeting has ended. Andersson et al. (2002) provide some suggestions on how this communication could be processed and accessed afterwards.

A likely consequence is that a presentation would not necessarily be centred on one person talking through a fixed deck of slides, but about a team meeting up and creating something together. The slides would provide a starting point in a collaborative and partially improvised experience, rather than being a rigid script.

5.2 Mesh networks for collaboration

5.2.1 Location

A significant outcome of the evaluation session was the importance that location has on the success of a meeting or presentation. In this sense, mesh networks could become very relevant in collaborative contexts by letting a team easily change location while remaining securely connected, without necessarily depending on pre-existing network infrastructure or centralised servers. There is a promising design space for applications that take advantage of these situated and flexible network configurations.

5.2.2 Voice

At one of my meetings with Terranet personnel, it was pointed out that, since the transmission rate of the mesh network is enough to support voice, this could be used to allow the audience to listen to the presenter with their phones. This would be convenient for situations where the place doesn't have loudspeakers available, or when the user has a hearing condition.

It could even work both ways, with the audience in a large auditorium being able to use their phones to ask questions, removing the need for passing portable microphones around.

5.2.3 Local and remote

The design as it stands assumes that everybody is sharing the same space and does not contemplate remote attendees.

From the technical point of view, it would be possible to set up a bridge between the mesh network and the Internet. The current design might still work well if such a connection is unidirectional, so remote attendees may get the content that is being shared.

However, allowing remote people to take active part in the meeting would need deeper changes to the design. It might even be a reason to replace the mesh approach with more traditional solutions based on infrastructural networks and central servers.

5.3 IoT for augmented spaces

5.3.1 Smarter projectors

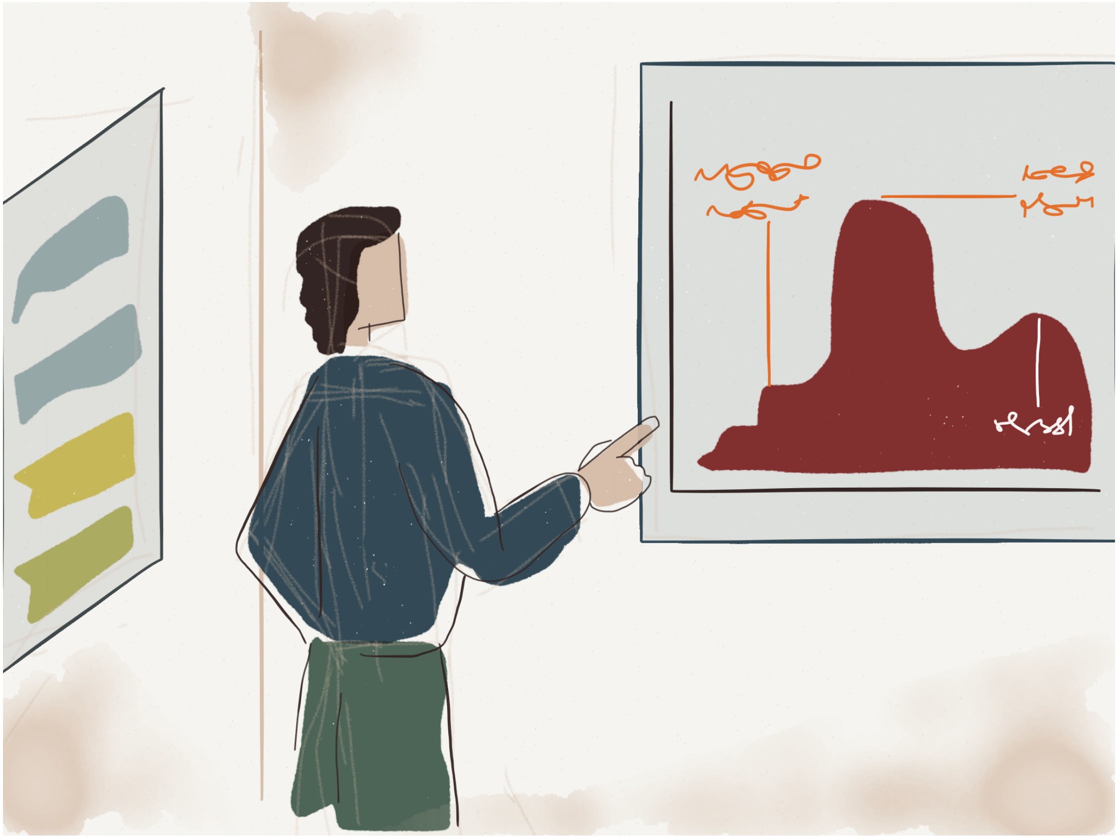


Figure 5.3: Standalone projectors used to plot changing data.

In the previous chapter, I speculated with the possibility of having projectors that would be able to join the mesh network by themselves. I don't consider this to be a far-flung possibility, given that such a device may be prototyped today by simply connecting a smartphone or small computer to a regular projector. There are already a few initiatives to commercialise smart projectors[3][4], and it is likely that more will appear in the near future.

Hence, there could be a future line of research about how to design and take advantage of these IoT projectors in the workplace. For instance, if we have a projector that can join the network and work semi-independently, it could be used as a dashboard to display real-time data or a video stream.

Citing Bret Victor[5], if you are working on a extremely complex system, "you have to build a room so you can go in and understand everything that is going on". Rather than designing and using each new device one by one, a holistic

[3] Beam, `http://www.beamlabsinc.com`

[4] Favi Pico+, `http://www.favientertainment.com/collections/pico`

[5] "Seeing Spaces", `https://vimeo.com/97903574`

approach could combine them to create spatial environments that help people visualise and reason with dynamically changing data. Thinking, reasoning and communication can often benefit from tools that are spatial, tangible, flexible and messy.

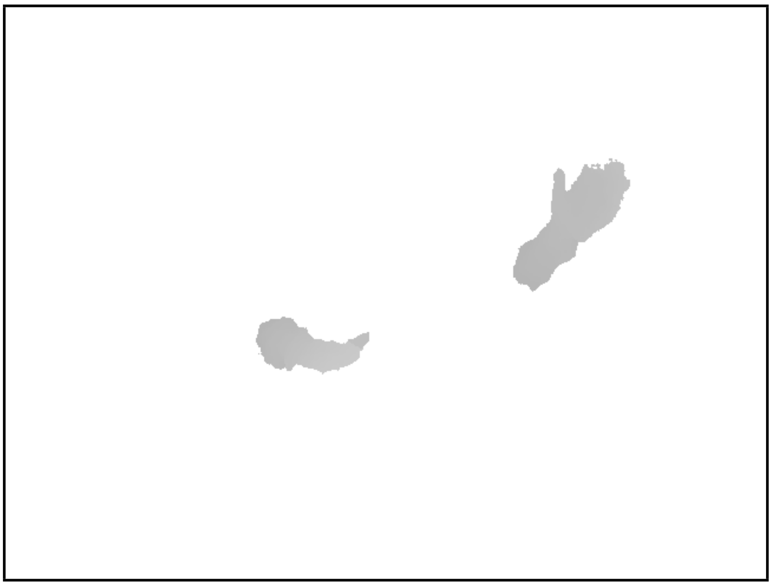
This links back to several of the augmented rooms discussed in the literature review. However, a significant change is that, instead of designing large installations, technology may now make it possible to achieve many of the same benefits through the flexible recombination of a diverse set of small components and devices.

5.3.2 Ephemeral paintings

One appealing venue for research is the pairing of projectors with movement capture and physical paper. I have carried out two early experiments along this line, although there is still much left to do. This work is included here as inspiration and to support the argument that the technological materials are opening rich paths for design research in this field.

As an early exploration of possible uses of projectors for creative purposes, I developed an tool for the dynamic creation of fleeting visual art. The movements of the user are captured and used to paint on the projection. The prototype uses a Kinect camera connected to a computer running a custom-made application written with the `OpenFrameworks` toolkit. The sequence of images in page 36 and following show how the image processing works.

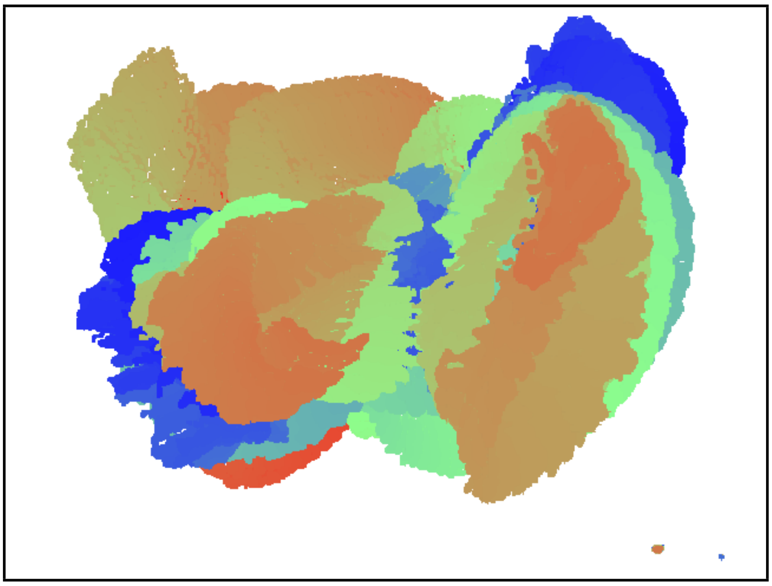
This is the raw depth image returned by the Kinect camera, at a speed of 30 frames per second.



A threshold is applied to the depth image. Its value has been tailored to the space so only the arms of the user remain in the picture.

To calculate movement, we find the absolute difference between the image above and the one from the previous frame.

This difference, this movement, becomes our brush and its colour changes over time.



The brush for the current frame is added to the ongoing sequence. The screen is cleaned after 20-30 seconds.

The point of this exploration was to look for creative uses of movement capture and projections. A more elaborated example, although focused more on technology and interaction than on aesthetic expression, is provided by Wilson and Benko (2010).

I chose to focus on this example partially because of its aesthetic qualities, shown in figures 5.4 and 5.5. There is something pleasant (and not quite captured in a static image) in seeing colour move and come alive, specially on paper. Augmenting rough physical materials is a powerful strategy for engaging the imagination.

This small experiment is intended to provide inspiration and raise questions rather than answer them: what could be expressed with this? and what would be the final output?

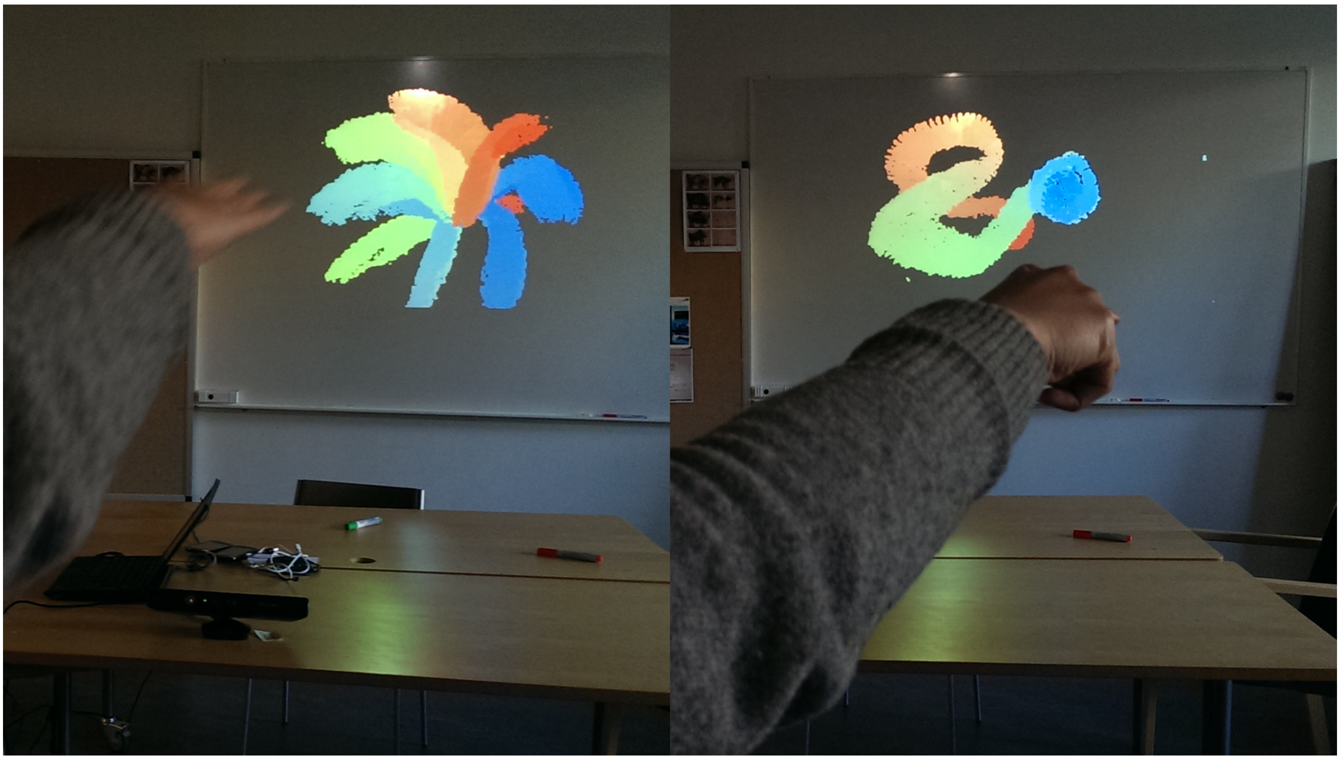


Figure 5.4: The installation in a classroom space, projecting on a whiteboard in front of the user.

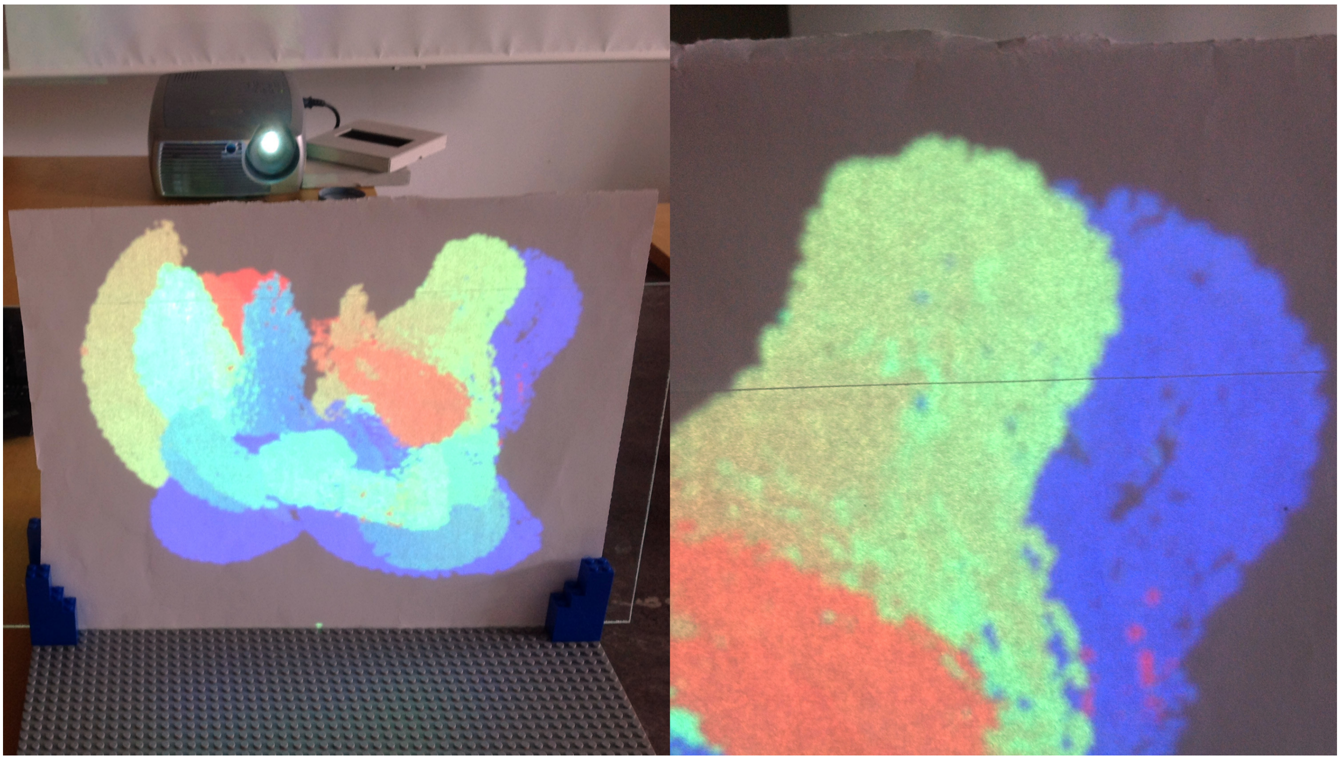
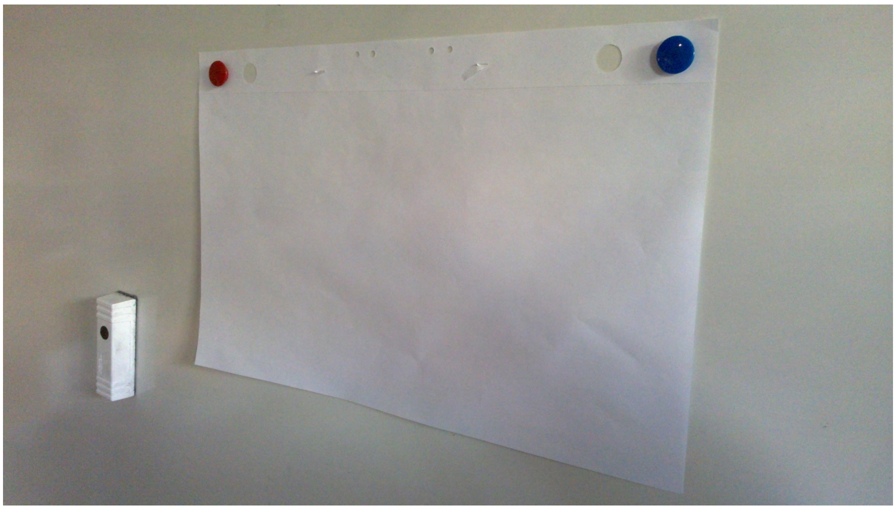


Figure 5.5: Set-up for back-projection on paper, and detail. Note how the texture from the image combines with the grain of the paper.

5.3.3 Sketching with projectors

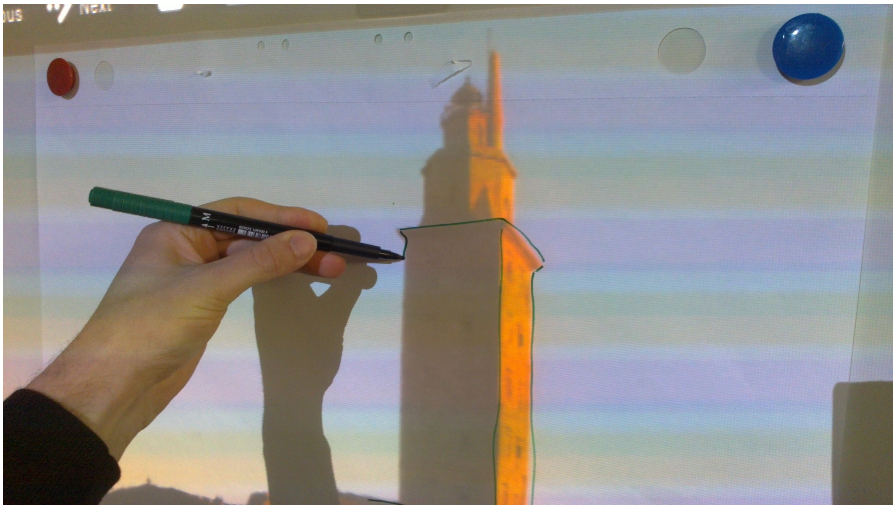
This design concept explores the use of a projector to provide references in the creation of drawings on paper, along the lines of Kim et al. (2013). The images in page 40 and following illustrate a quick sketch using a whiteboard, a projector, paper and a couple of magnetic pieces.

This set-up allows us to explore some of the benefits of using flexible projection to help with creating sketches on paper. Several questions come to mind. The first one is how the projected image can be selected and manipulated by the user. The second is about what the outcome of the previous process should be: a virtual document, some sort of mixed media that joins physical and digital content, or a simple sketch on paper.

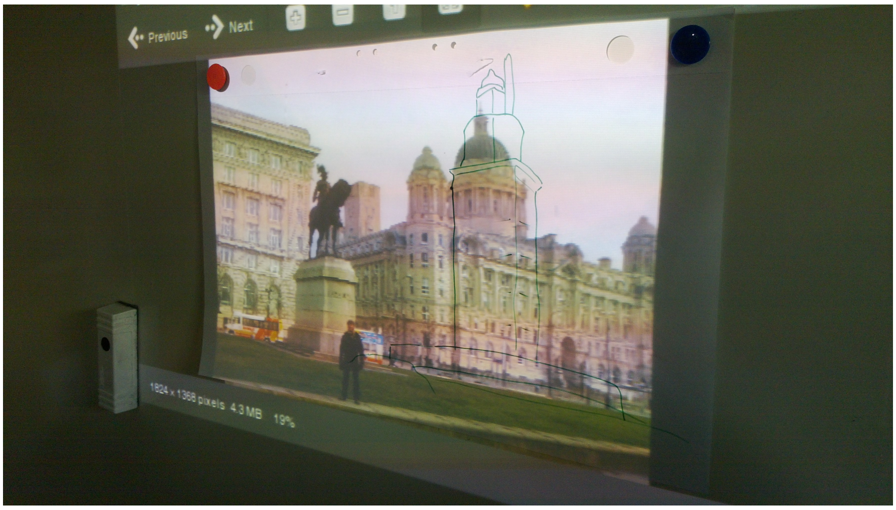


First, we attached the paper to the whiteboard using the magnetic pieces.

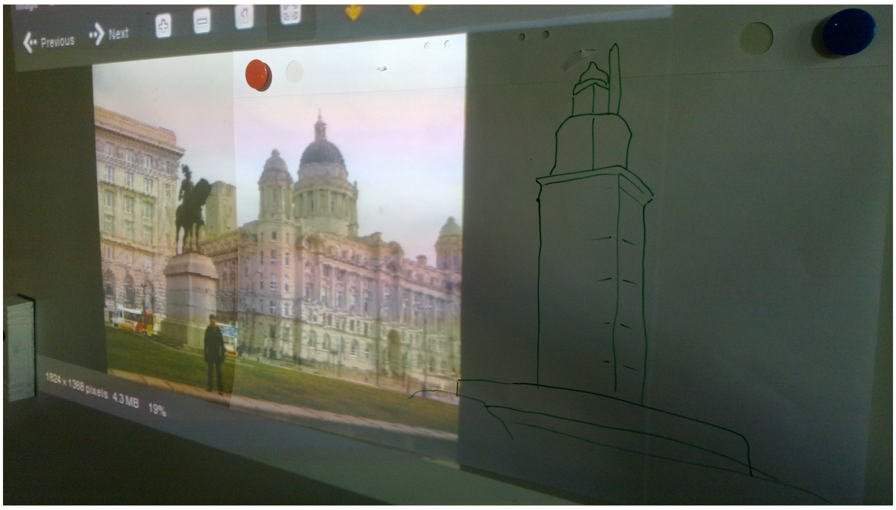
The projection was then adjusted so the desired image would fit the size of the paper.



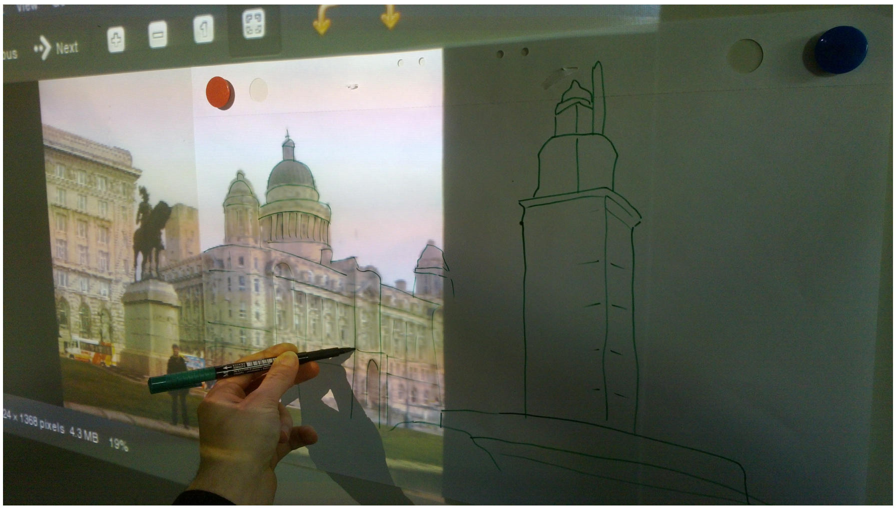
This projection was used as an aid to create a quick sketch.



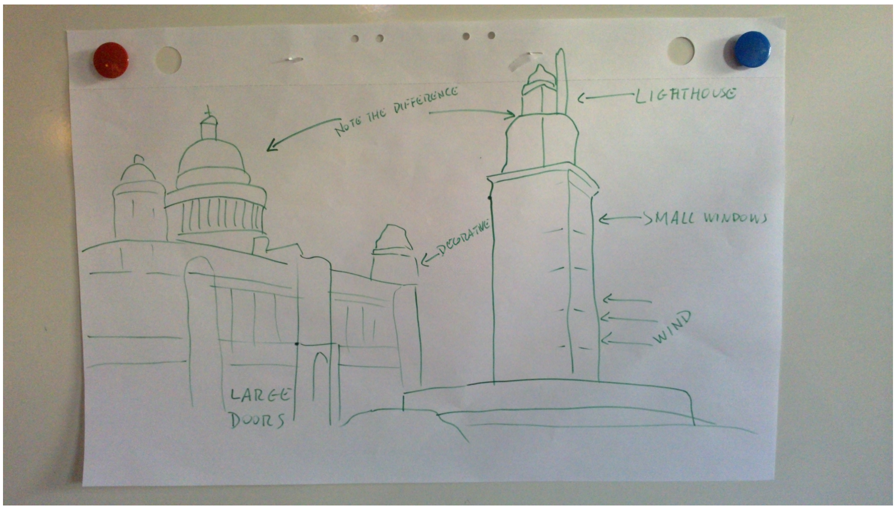
A new image was selected.



We were able to simulate the capability of moving the projected image by displacing the paper along the whiteboard.



The second image was then used to extend the sketch.



The resulting sketch could then be annotated and used to reason about the topic at hand.

Figure 5.6 shows a rough envisioning of a device that uses connectivity, projection and motion capture to implement the same basic functionality. The projection could be on top or (more visually pleasant) below the paper. Movement of the non-writing hand could be used to manipulate the digital content ("pen writes, touch manipulates", Hinckley et al. (2010a)). Content could be provided through a connection with the user's phone or laptop.

Using this device, the user would be able to browse phone images, move and scale them, and integrate them in sketches on paper. What would be the value in doing this? Going back a couple of paragraphs, there is a fourth possible outcome of this process: a better understanding of the problem at hand, with projection and paper being just temporary tools to aid reasoning.

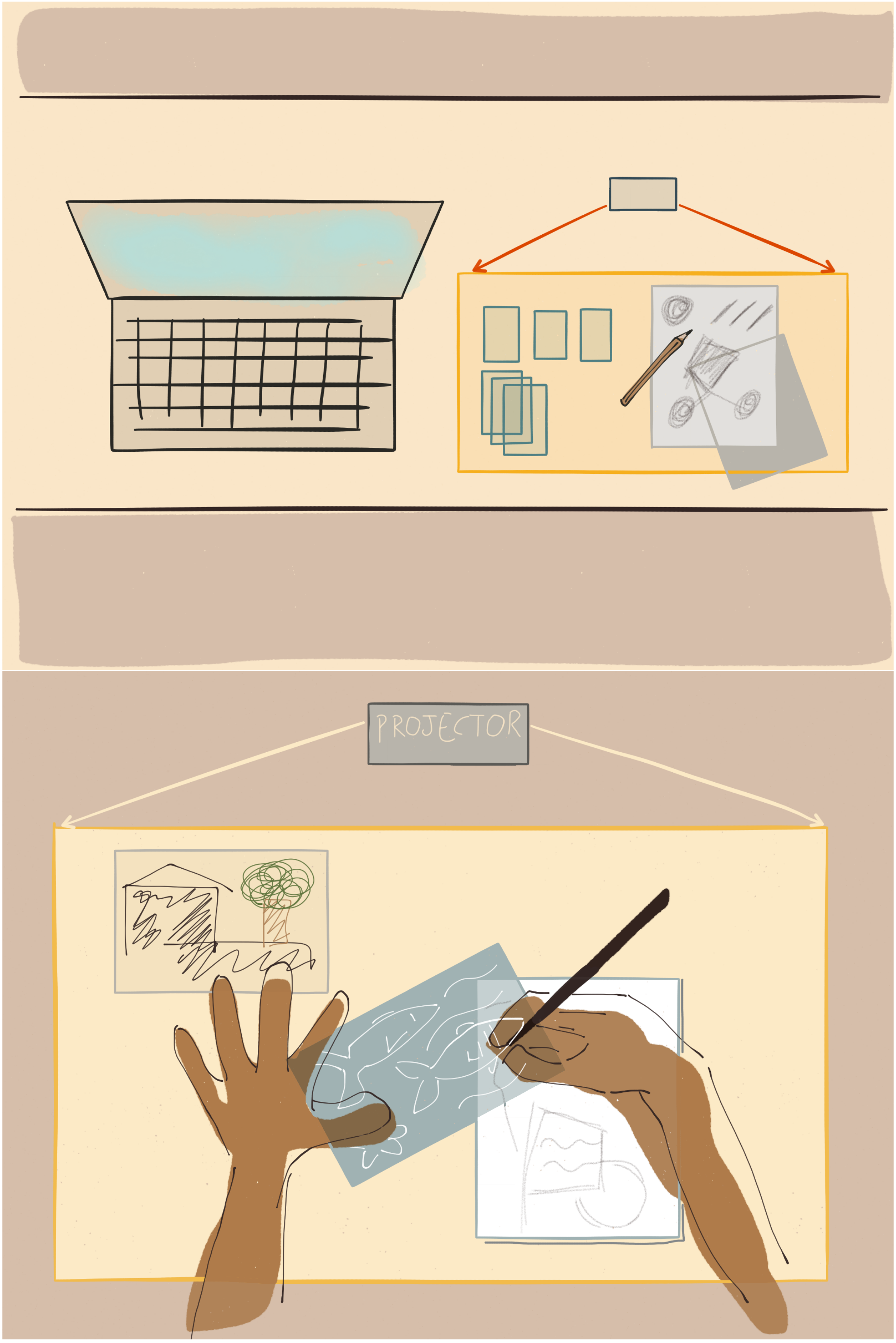


Figure 5.6: Two top-views of a possible device for sketching, using projection and gestures.

5.3.4 Augmented spaces

In the literature review, we saw examples of complete smart rooms like Haller et al. (2010). This work led to frameworks such as the "blended spaces" proposed by Benyon and Mival (2012), where the information architecture and the topography of both people and devices need to be specified and carefully thought out.

What I have come to realize as I explored the topic of emerging configurations in the workplace is that perhaps we don't need these large ad-hoc installations to get the same benefits in terms of visualisation, spatial distribution of data, reasoning, and communication. Many of those could be achieved by mixing smaller modular components, with an adequate distribution of roles and functionality, and with the flexibility to be appropriated and reconfigured as needed. Following Wäljas et al. (2010), we could see the room itself as delivering a cross-platform user experience. The elements that take part in this experience would need to provide appropriate composition, fluid task migration, and consistency across platforms and devices.

We should keep in mind that workplaces accommodate communities of practice with a lot of implicit knowledge and collaboration strategies. Digital solutions should be flexible and adapt to their context and audience, rather than try to make humans adapt to digital technologies

So what would be the components in this emergent ecosystem? Some of them we already know: smartphones, tablets and personal computers. There is already a great amount of existing work focusing on their interplay.

A new element could be the smarter projector discussed earlier, able to join the mesh network and display content independently as a dashboard.

As I tried to express in the previous sketches, movement capture could be combined with other technologies to provide greater flexibility and expression.

Following Sellen and Harper (2002), paper would still have a place in these augmented spaces, perhaps in combination with projection and movement capture. Maybe this could mean that the next device to join this augmented space would be an augmented pen (Vogel and Casiez, 2011)

These configurations could leverage implicit knowledge about how the real world operates, and about how we understand and perceive ourselves, others, and our environment (Jacob et al., 2008).

At this point, it should be clear that this is just a vision for future research. My main argument here is that there is an opportunity to discover rich interaction possibilities in the fluid combination of IoT technologies in the workplace.

Rather than focusing on creating a holistic solution from the start, my opinion is that this research should take an approach not unlike the one followed throughout this project: research the technology and design materials, understand the context of use, and then focus on improving concrete experiences by making them more productive, more enjoyable, and more rewarding.

Chapter 6

Conclusions and Discussion

In terms of how to make meetings and presentations more collaborative, the main contribution is twofold. First, the identification of opportunities to create a social choreography using physical gestures to stablish connections between devices. Second, the proposed interaction for requesting and handing over control of the projector, which may help make the collaboration between audience and presenter more fluid.

Furthermore, there is the relevant (if not too novel) confirmation that current technology makes it feasible to collaboratively carry out presentations using the attendees' smartphones. Following our approach, meetings may become more collaborative events where people participate in creating a common understanding through a shared collection of insights and references. In consequence, this means that the original set of slides would not be sufficient to provide a summary, as the audience's contributions should be included as well.

The design needs to accommodate different audience configurations, which among other things would require more types of notifications and requests. It might also be necessary to create some kind of token-based system to accommodate multiple presenters. Additionally, there is a need to share more kinds of content in addition to slides and images, as well as to be able to point at features on the current slide.

Mesh networks appear to have potential to improve collaboration in work contexts through their benefits in terms of flexibility and security. The design shows that the set-up process can lead up to interesting social choreographies. The collaborative evaluation highlighted the importance of being able to choose the right location for a meeting. However, the integration of remote attendees in the applications used within the mesh network could be a challenge.

A more general outcome of this project is the hint at the opportunities that open up when we are able to connect smart IoT devices in the workplace space.

In our particular case, a projector which is able to join the mesh network would make the interaction more fluid and natural, allowing the presentation to be carried out collaboratively without the need to fiddle with cables.

Smarter projectors have potential to aid in the dynamic creation of flexible workspaces. When combined with personal computers and motion tracking, they could provide many of the benefits of the large installations discussed in the literature. The previous chapter included a small exploration about how these richer interactions could benefit the case of one person sketching on paper or with movement, and there are certainly more venues for research in the combination of IoT technologies for the creation of augmented workspaces.

6.1 Critical discussion

I now take Zimmerman et al. (2007) as a guide for a discussion of the rigor, invention, relevance and extensibility of this design research project.

The process started by reviewing academic research and gathering insights about the problem domain, before focusing on the concrete design problem. A design solution was created and prototyped, then used as a prop in a collaborative evaluation session. The insights gathered in that session, as well as during more informal evaluations carried out throughout the development phase, pointed at several relevant future lines of work.

This method comprised, to different degrees, three of the strategies outlined by Löwgren (2007): the creation of a prototype for the evaluation of design ideas, the examination of the potential of new design materials such as mesh networks, and a final exploration and reflection about possible future.

In the report, I have attempted to convey the design qualities of the different artifacts through the use of abundant graphical material to complement the written explanations.

In general, the limitations of the prototype didn't get in the way of it demonstrating the concept: the main exception to this is that creating a connection to the projector is not entirely hassle free, as I'm using a special cable to mirror the screen of a smartphone.

As useful as the evaluation was, it would have benefited from a more realistic set-up and content. For example, the prototype should have been used to deliver a real presentation, but this was not done because of time constraints.

The main contributions of the project are relevant and valuable, even if the general idea of connecting smartphones and projectors is not new. The considerations that came out of the prototyping and evaluation phases define concrete next steps to extend and evolve the design.

The last section of chapter 5 presents a broad argument about using IoT for the flexible creation of augmented workplace. This is to be seen as an attempt to generalize from a concrete problem, providing insight into the more general problem domain (Obrenović, 2011). In that sense, my aim was not to find definitive answers but to put forward the questions which could be most suggestive for future research.

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